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EDITORIAL NOTES

CREOSOTE FOR MOTOR TRANSPORT

WE referred in these columns last week to the scheme of the Mines Department and the Ministry of Transport to promote as fuels for commercial motors certain coal-tar oils, such as creosote and similar products (excluding light oils and heavy oils). The aim is to encourage experimental work on the use of these oils with a view to reducing the consumption of imported fuels. We mentioned that considerable work on the employment of creosote for commercial vehicles has already been carried out by gas undertakings. Notable examples where practical experimental work has been undertaken are provided by Belfast and Salford. This, of course, was peacetime investigation ; as a matter of fact, tests were begun at Belfast as long ago as 1929, at which time coal-tar oil sold in the ordinary way was fetching only a penny a gallon, which was almost tantamount to giving it away. The Chemical Works of the Belfast Gas Undertaking therefore decided to wash the light creosote oil with caustic soda and add 10% of solvent naphtha. A quantity of 15% of tar acids was left in the oil, the flash point being 128°F. Trials undertaken by the Belfast Omnibus Company showed the desirability of employing a special type of carburetter, and of preheating the mixture after it left the carburetter. A separate tank was used to contain the oil.

The work at Belfast was described by Mr. J. D. Smith, Engineer, Manager, and Secretary of the Gas Department, in his Presidential Address to the Waverley Association in 1931, and in view of the present circumstances and the obvious desirability of fostering the employment of tar oils as substitute for imported motor fuels we think it useful if we call to mind again some of the findings as recounted by Mr. Smith at that time. Starting-up of the engine was effected in the normal way by petrol, and then the petrol was turned off and the oil turned on. Extensive trials proved that the oil was eminently satisfactory for motor traction work. On one run, the mileage obtained with coal-tar oil was 12 m.p.g., compared with 8 m.p.g. on petrol ; moreover, the tar oil eliminated "knocking." Other important advantages of the creosote oil are that, owing to its high flash-point, it is pre-eminently safe to use, and, because of its composition, the exhaust gases are almost free from carbon monoxide. Actual tests on the exhaust gases of two 'buses, one running on petrol and the other on the washed tar oil, showed that, whereas the carbon monoxide content with petrol was 4.2%, with the tar oil it was only 0.3%. The only expense involved in the conversion of petrol engines for use with tar oil would be the provision of an additional carburetter, a manifold, and a fuel tank. At the time Mr. Smith gave the production cost of the creosote-naphtha mixture as 4d. a gallon. Since then, of course, costs of production and market conditions have necessarily greatly changed. But the Belfast results provide a source of encouragement.

So do the results obtained at Salford, where experiments were conducted in 1932. The system made use of a combined exhaust and manifold system, the creosote vapour, as in the Belfast experiments, being subjected to heat before being introduced into the cylinders. From the driver's point of view it would seem that a vehicle running on creosote is hardly as responsive to the throttle as a 'bus running on petrol, and a certain amount of care has to be taken when using the accelerator. As regards pulling power, however, it is the equal of any petrol-propelled vehicle. Even in peacetime, with plenty of petrol for all, the results of the use of creosote as motor fuel could be regarded with satisfaction. Wartime conditions, coupled with the scheme set in motion by the Mines Department and the Ministry of Transport, should give impetus to the development of its use and improvements in the systems employed. The experimental work already undertaken, to two instances of which we have referred, may prove immensely helpful at the present juncture.

UNACCOUNTED-FOR GAS

WE publish in to-day's "JOURNAL" an extract from the First Report of the National Gas Association of Australia. It is concerned with unaccounted-for gas—a survey of the problems and of recent investigations thereon. It was undertaken by Mr. A. S. Fitzpatrick, Chief Research Officer of the Association, and it constitutes a full and extremely helpful work on this important problem. Consideration has been given to the difficulties of defining unaccounted-for gas in terms of percentage of gas made and per mile of mains and services, and other bases. The causes of inaccuracy of station and service meters are discussed and methods of testing are described. Special attention is given to the value of testing service meters *in situ*, especially for accuracy of registration at low gas rates. Leakage from holders, mains, and services is also discussed, and the report includes a very useful account of recent work on soil surveys, pipe coatings, and joints. The standard methods for the analysis and expression of unaccounted-for gas formulated by The Institution of Gas Engineers and by the American Gas Association are set out, and, quite rightly, emphasis is laid on the desirability of employing a uniform method of expression for unaccounted-for gas in Australia.

Considering the problem of unaccounted-for gas in Australia as a whole it is obvious that the major causes are not the same for different undertakings ; in one case most trouble is due to leakage from mains and services, in another to leakage from holders, in another to inaccuracy of service meters. The observation is made in the report that it is unlikely that many small Australian gas undertakings can be rescued from their "parlous state" unless a careful analysis is made of their unaccounted-for gas. Knowledge of the facts is the first essential and the second is action to remedy the faults. The conclusion is drawn that the position of the Australian Gas Industry with regard to unaccounted-for gas must be regarded as most unsatisfactory. If it be assumed that the methods of expressing the total figure are accurate, then it is a severe indictment of present practice that coal, carbonizing plant, and labour are being used in producing approximately 2,265 million cu.ft., or 12% of the total make, which is never sold. On the other hand, if the present methods of expression for unaccounted-for gas are

incorrect, what it the truth? It is unlikely that the whole of the 12% is loss by leakage; a part may be due to lack of application of corrections or to faulty metering at the works or on customers' premises. Unfortunately, however, it may well be that the condition is worse than at present appears. What is obviously needed is a sound and agreed basis for expressing unaccounted-for gas, and we are glad that recommendations in this regard are to be embodied in a further report on the subject by the Association.

PATENTS IN WARTIME

A QUESTION which, though not peculiar to the Gas Industry, has, we know, suggested itself to makers of gas appliances concerns the position of patents during the war. With so many plants fully occupied on national work, cover periods for patent and other registration rights in connexion with their normal products are running on without the owners being able to derive full benefit from them. There is even a feeling in some quarters that the Government should arrange for an automatic extension of the cover, up to the period put in abeyance, subject to the payment of appropriate fees. Enquiries we have made show that this feeling is not at present shared by experts in the administration of patent law, who are of the opinion that such a far-reaching move would not be in the best interests of the country as a whole. That is not to say that they do not recognize the substantial grounds that industry has for relief from the costly and complicated procedure normally involved in securing extension of its patents, but they point out that there is already in operation some provision in that direction, and they have little doubt that this provision will be generously interpreted at the appropriate time.

The existing law provides for the operation of a patent for a period of 16 years, subject to the payment of renewal fees each year during the life of the patent. At the end of that time the patent may be extended for a further period of five years, or in exceptional cases for ten years, if it can be proved that the patentee has been inadequately remunerated for his patent. Special provision was introduced in 1919 for the benefit of patentees who had suffered as such through hostilities, whether the loss arose from difficulties in regard to manufacture or from the fact that the patentee was engaged on national service. This provision, which stands as part of the present Act, extends, however, only to a simplification of the form of application for extension of a patent—by originating summons instead of by petition—in which the applicant says, in effect, that part of the term of the patent has been taken away from him by causes beyond his control, since the war years were really useless, or worth only a fraction of their normal value.

At the end of the last war there was no automatic extension of patents, but between 1914 to 1918 there were many cases in which regular payment of the renewal fees was not maintained, and at the conclusion of hostilities, and for some time afterwards, the patentees were given the opportunity of paying up the arrears. In the present war the Patent Office appears to be taking a cautious line with regard to interrupted payment of fees and is not, in general, regarding patents as finally lapsed merely because of non-payment. An important point raised by those manufacturers who view the future with some uncertainty is that many patents are also taken out in the Dominions and Colonies, and extensions in these cases would, of course, take considerable time to arrange. Overseas authorities, however, usually follow the procedure of the Mother Country in dealing with such questions, so that a ruling given here would be of great importance.

Congratulations to Davis's

A brief note in the news this week refers to the Jubilee of a well-known firm in the Gas Industry—the Davis Gas Stove Company, Ltd., having been registered in 1891. However, the Davis family connexion with gas goes further back than this, since Mr. Henry Davis made and sold gas stoves as long ago as 1879. Congratulations to his son, Cyril G., Chairman and Managing Director, to his grandson, Kenneth N., Joint Managing Director, and to the whole firm which is such a virile component of Radiation, Ltd.

Personal

Mr. E. F. SMALLBONE, A.M.I.C.E., Engineer and Manager of the Broadstairs Gas Company, it to take over a similar position with the Herne Bay Gas Company, combining the duties of both posts.

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Mr. J. D. MARCH, who for the past nine years has been associated with the Bath Gas Company, chiefly on the laboratory side, has been appointed to the position of a technical assistant to the Hampton Court Gas Company.

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Barnoldswick District Council have appointed Mr. R. N. WEBB (Bramley) as Gas Engineer for such period as Mr. H. SPENCER (who has obtained a Commission in the Royal Engineers) is absent on military service. Before retiring on superannuation in 1938, Mr. Webb was for 34 years Manager of the New Wortley Gas-Works of Leeds Corporation.

* * *

Mr. R. K. LAW, who was Assistant Gas Manager at the Marple U.D.C. Undertaking, last week took up new duties with the Woodall-Duckham Vertical Retort and Oven Construction Co., Ltd. Mr. Law is a son of Mr. J. L. Law, Engineer, Manager, and Secretary of the Marple Undertaking.

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In last week's "JOURNAL" we stated in error that Mr. W. A. Cook had been appointed Works Superintendent of the Warrington Gas Department. Actually it is Mr. W. A. PASK, of Oldham, who has been appointed to the position.

* * *

Mr. ROBERT BROWN, Engineer and Manager of the Catrine Gas Company since 1916, has retired after 28 years' service with the Company. Prior to his appointment as Engineer and Manager, he was Assistant for four years. To mark his retirement, he has been presented with a wireless set by the Board of Directors, employees and friends. Mr. Brown's successor is Mr. ROBERT A. HARVEY, who for the past 22 years has been Engineer and Manager at Lockerbie.

Obituary

The death occurred on January 17 of Mr. REGINALD BOWDEN, who served as Superintendent of the Braceborough Gas-Works for 25 years. He retired last September.

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His many friends in the Industry will be sorry to hear of the death, on Jan. 16, at his home in Southport, of Mr. J. T. KNOWLES, for many years chief representative in the North-Western Area for Fletcher, Russell & Co., Ltd. (Radiation Ltd.). Mr. Knowles had given over 50 years' service to Fletcher, Russell & Co., Ltd., retiring in July, 1939.

Further Awards for Gallantry

The Gas Industry is again represented in a further list of awards for gallantry published in a supplement to the *London Gazette* last Friday night.

Mr. JOHN GRAYSTON, Engineer to the Romford Gas Company, and Mr. B. V. POOLE, Shift Foreman with the same undertaking, receive the George Medal. According to the official account, bombs dropped near a group of gasholders fractured the return main, and escaping gas was ignited. Unconsumed gas from other fractures gave rise to the grave danger of a serious explosion. Mr. Grayston and Mr. Poole entered blazing premises, climbed over a 15-ft. high timber platform which was on fire, and closed the main gas valves. Other recipients of the George Medal include Mr. A. E. PAGE, valveman, of the Gas Light & Coke Company.

The Medal of the Order of the British Empire (Civil Division) goes to Mr. H. G. T. GARDINER and Mr. E. F. BAKER, fitters, Mr. T. HIGGINS, retort stoker, and Mr. W. A. STILL, yard attendant, all of the Gas Light & Coke Company.

A Meeting of the Board of Examiners of the Education Scheme of The Institution of Gas Engineers will be held at 1, Grosvenor Place, London, S.W. 1, on Tuesday, Feb. 11.

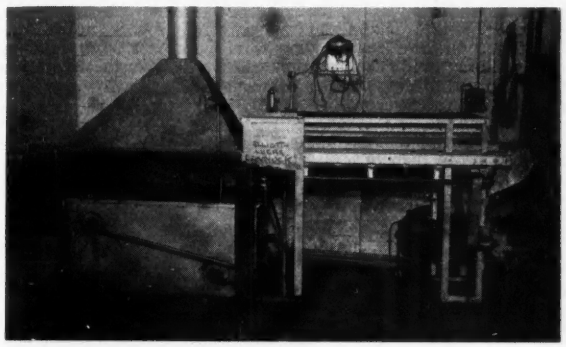
The Next General Meeting of the Manchester and District Junior Gas Association will be held on Saturday, Feb. 1, at 2 p.m. at the Engineers' Club, Albert Square, Manchester, when Mr. J. B. Walsh —Assistant Distribution Engineer of the Stockport Gas Department —will read a paper on "The Co-ordination of High and Low Pressure Gas Supplies."

A Proposal to Install Plant, at a cost of £200, for the supply of gas to vehicles was considered by the Dundee Corporation Gas Committee on Jan. 20. The question was raised as to whether there would be a demand for the service unless gas could be supplied in compressed form. The proposal to install the plant was carried by five votes to four.

The Council of the London and Southern District Junior Gas Association have decided that in view of the present difficulties, and the impossibility of making any plans ahead, no further attempt be made by the President and the Hon. Secretary to promote activities of the Association for this Session. The current subscription will be waived, and those who have already paid will be repaid.

A New Tool-Hardening Furnace

With a view to further increasing their output, Messrs. Elliott Lucas, Ltd., of Bridgetown, Cannock, manufacturers of pliers, have lately installed a "Hoyelt" gas-fired conveyor furnace of their own design. The furnace, which is illustrated here, is fitted with Brayshaw burners, and the full traverse of the conveyor is 58 in. The speed of travel is regulated by a geared mechanism which will pass tools for hardening from end to end of the conveyor in 7 min. 50 sec., 5 min.



15 sec., or 3 min. 55 sec., in first, second, or third gear respectively. The rate of delivery of hardened pliers is 648 per hour. Where this furnace is used for chisels or other tools which set more closely, the throughput per hour would be considerably in excess of this figure.

The hardened tools are delivered automatically into an oil-quenching bath, from which they pass by means of a second automatic conveyor belt into a drying tray. The advantages claimed for this furnace include a 50% reduction in labour and the highest degree of standard accuracy of hardening. The amount of heat introduced into the urnace is adjustable as between the use of four to nine burners. When the full number of burners are employed the gas consumption amounts to 800 cu.ft. per hour.

The Institution of Gas Engineers

Education Calendar, 1941

Jan. 31 : (i) Last date for receipt of applications from students who desire to be examined in ancillary subjects. (ii) Last date for receipt of special applications from principals in respect of internal Candidates for Minor Course and Gas Fitting Certificates. (iii) Last date for the receipt of applications from external students for exemptions (Minor and Major Course Examinations).

Feb. 1 : Last date for receipt of applications from students for recommendation to the City and Guilds of London Institute for examination as external candidates in Gas Supply Practice and Gasfitting.

Feb. 28 : Last date for receipt of College Estimates of Entries.

Mar. 18 : (i) Last date for receipt of applications to sit for the Ordinary and Higher Grade Examinations from external candidates. (ii) Last date for receipt of applications to sit for Diploma Examinations.

April 30 : (i) Last date for receipt of Form G (names of Internal Candidates) and entrance fees from Colleges. (ii) Last date for receipt of Diploma Theses.

May 26 : (i) Card for "Permit to Sit" despatched to candidates with a copy of "Instructions to Examination Candidates." (ii) Examination Stationery and Question Papers despatched to Centres for Internal and External Candidates.

June 14 : Examinations in Gas Engineering (Manufacture) :
Ordinary Grade, 2 to 5 p.m.
Higher Grade (Part I), 2 to 5 p.m.
(Part II), 6 to 9 p.m.
Diploma Grade (Part I), 2 to 5 p.m.
(Part II), 6 to 9 p.m.

June 17 : Last date for receipt by the Institution of Candidates' Worked Answer Books in Internal and External Ordinary and Higher Grade Gas Engineering (Manufacture).

June 21 : Examinations in Gas Engineering (Supply) :
Ordinary Grade, 2 to 5 p.m.
Higher Grade (Part I), 2 to 5 p.m.
(Part II), 6 to 9 p.m.
Diploma Grade (Part I), 2 to 5 p.m.
(Part II), 6 to 9 p.m.
Examination in Gas Supply (Part I), 2 to 5 p.m.
(Part II), 6 to 9 p.m.

June 24 : Last date for receipt by the Institution of Candidates' Worked Answer Books in Internal and External Ordinary and Higher Grade Gas Engineering (Supply).

July 1 : Last date for receipt of Examination Results in Ancillary Subjects and completed Record Forms.

July 8 : Last date for return to the Institution of (i) all Answer Books from Examiners and Assessors, and (ii) Examiners' Reports.

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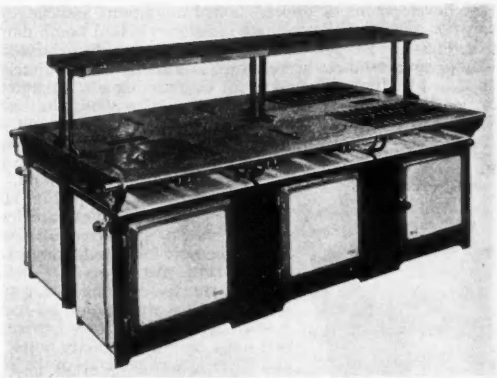
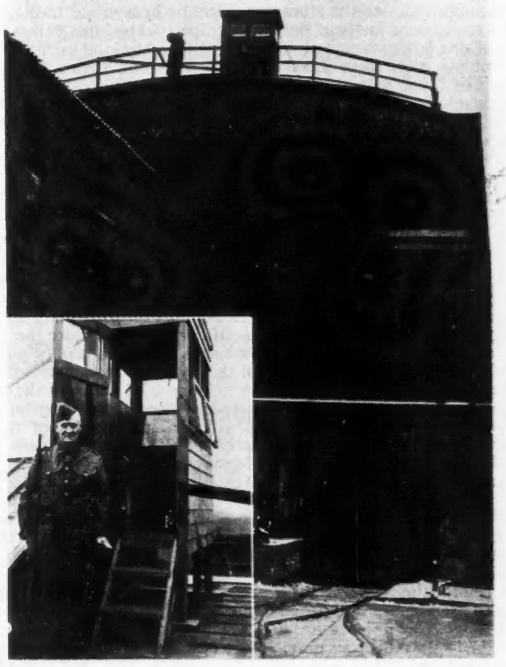
Parkinson Achievements in Australia

News has just been received from Australia, where Parkinson gas cookers enjoy a great measure of popularity and a reputation for efficiency, which typifies the important part being played by this branch of the Parkinson Stove Company, Ltd., in the Empire's war effort. For a large Military Hospital in course of erection in Melbourne they have recently completed a large heavy duty cooking unit designed and built in Australia. This is a six oven "Unita" range with two 9-ft. hotplates, the whole assembled in island unit form, surmounted by a special platerack grid. The illustration gives a good idea of this range,



the oven being the latest production of the "Unita" oven with a 24-in. wide door opening. The four external ovens are fitted with controls, and the hotplate consists of three double solid sections with concentric burners, and three open top sections with two boiling burners each. In addition to the range as described above, a battery of six similar ovens was also supplied for this job. Three double grillers of the No. 273 type with special sheet-iron hotclosets on top, and built on special angle iron stands, were also included in the equipment supplied for this hospital.

Further gratifying news of Parkinson successes in heavy duty cooking competition has also been received. In the Sydney Master Pastrycook's Exhibition the Parkinson No. 3024 ovens gained no fewer than 18 prizes out of 30 awards won by gas-cooked entries, covering a wide variety of items ranging from wedding and Christmas cakes to fancy meringues.



This lookout post was erected at the works of W. J. Jenkins & Co., Ltd., and has been in commission with a whole-time observer since May of last year. The hut is lined with armour plate, fitted with unbreakable glass, and is complete with map, armoury, binoculars, and telephone direct to the works A.R.P. post. This is believed to be one of the first lookout posts put into commission in the country.

Cutting Down Unaccounted-for Gas

PRESENT conditions give rise to a variety of circumstances in which the lessons of such experiences in dealing with leakages as those described by Mr. C. R. Ingham in his article on "Distribution of Gas in a Mining Area" in the "JOURNAL" of Jan. 15 (pp. 115–116) may be usefully applied. Besides the old and constantly recurring problem of mining subsidence there is the ever-increasing effect of vibration from modern heavy road traffic ; road and railway bridges are liable to disturbances, and there are the effects of temperature changes, especially in pumping mains. More recently still there has been the development of unprecedented conditions associated with the war, not only in the immediate vicinity of actual bomb damage, but sometimes at considerable distances from such disturbances.

All these circumstances serve to focus attention on the measures described in Mr. Ingham's article for overcoming gas leakages, and interest in the Dresser clamps and couplings to which he refers is increased by the fact that all these fittings, which were originally of American manufacture, are now being made in Canada and Great Britain. The Dresser patent leak clamp (Fig. 1) used in cases where lead joints are leaking and the need of an efficient and permanent remedy is indicated, comprises an anchor ring, placed on the socket, a follower ring fixed on the pipe, a special large reverse wedge section oil-resisting rubber gasket which goes between the two rings, and the necessary bolts, clips, and fillers. Serrated ends of the anchor ring sections provide a simple and effective means of adjustment and render possible a positive and snug fit on the socket. The diameter of the follower ring can be reduced or enlarged by removing or adding fillers, which permit a wide range of adjustment. The fillers are of the same size and shape as the follower ring sections to give a continuous backing for the gasket, with no gap in the gasket recess. The rubber gasket extends well beyond the caulking space and is closely confined by the follower ring, which is designed to compress the gasket in the proper direction to ensure an efficient seal at every point under the gasket, both on the face of the socket and on the spigot of the pipe. The original makers produced a complete range of sizes, from 4 in. to 48 in. inclusive, though at present not all the intermediate sizes are in production in this country.

FIG. 1.

The commonest cause of such leakages as are dealt with by these clamps is ground settlement in colliery districts, and up to date in one such area about 1,000 of these clamps have been utilized. Hammering on the mains, due to the vibration set up by heavy road traffic, which tends to squeeze the lead out of the pipe sockets, has called in the case of one large municipal undertaking in a Midland manufacturing district for more than 2,000 clamps of various sizes. An annual saving of more than 2%, representing several million cu.ft. in its unaccounted-for gas, is attributed by the management to the adoption of this means of reducing leakage. In another area constant trouble arose from the joints of three 21-in. mains carried over a railway bridge. The application of 300 Dresser leak amps immediately cured the persistent leakage.

Temperature variations in pumping mains have been found to cause leakages. The gas discharged from the compressors is generally several degrees above ground temperature, and this temperature rise expands the pipes. When pumping ceases the pipes gradually return to ground temperature, with consequent contraction. This alternate expansion and contraction, though very minute, eventually leads to a creeping of the lead and slight leakage. In one works in the Home Counties, a series of leaking joints were found in a 30-in. pumping main within a limit extending about 200 yards from the compressor plant. In a large Midland town, 100 clamps were used on overground mains subject to expansion and contraction.

The Dresser coupling, described in Mr. Ingham's article as being used for connecting up all new steel mains, takes the place of the ordinary socket and spigot lead joint, and produces a strong flexible joint that takes care of all expansion and contraction in the pipe. The coupling (Fig. 2) is equipped with an indestructible gasket. The body of the gasket is of a highly compounded but resilient composition, which in itself offers considerable resistance to the destructive action of drip oil or other condensates. At the same time it is protected by lead tips or specially treated duck tips, either of which seals the gasket from contact with the contents of the pipeline.

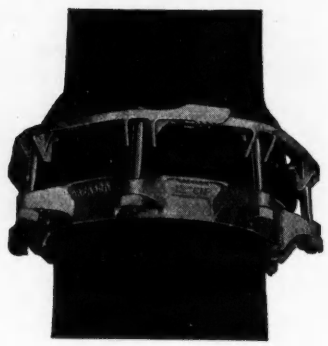


FIG. 2.

The coupling can be assembled even in water-logged trenches. Where abnormal expansion has to be provided for, the inner ring can be supplied from 5 in. long to as much as 24 in. The coupling has been tested and found gastight under pressures up to 1,000 lb. per sq.in. The use of this type of coupling has resulted in the reduction of leakage in one provincial colliery town, where ground movement was excessive, from about 30% to as little as 8%.

FIG. 3.

Similar in operation to the mains coupling is the Dresser service coupling (Fig. 3), also extensively used in Mr. Ingham's area at Cannock. Here again the joint is made by the compression of rubber gaskets on plain-ended pipe, and an important advantage from the fitter's point of view is that for assembling the coupling an ordinary spanner is the only tool required. Large numbers of these small couplings have been used by gas undertakings in various parts of the country. They are fixed near to the bend or elbow screwed into the main, so that any ground movement can be taken up without fracturing the connexion.

"Knowledge and Power on Tap"

This caption is taken from an article by Mr. H. D. Madden in this year's annual trade supplement of the *Western Mail and South Wales News*. We congratulate Mr. Madden on continuing his good work, in the present circumstances, of keeping gas before the public eye, and we congratulate the newspaper in question on not only the size (32 pp.) but also the quality of the contents of its supplement.

Research, observed Mr. Madden in his article, has been the key to all progress in every development in which the Gas Industry has been interested—from carbonization of coal to combustion of the gas flame at the consumer's burner, whether for domestic or industrial use.

" This research," wrote Mr. Madden, " undertaken jointly by furnace makers and the Gas Industry, has produced notable advancement in the application of town gas to the problems of the industrialist where the use of heat is essential in the production and fabrication of all metals and alloys. At the gas-works great skill and scientific knowledge are applied to produce a clean fuel of unvarying quality which subsequently can be used in highly efficient furnaces specially designed for the particular work for which they are required, and this combination of fuel and furnace efficiency gives the manufacturer the control over the finished product which is so necessary.

' The list of industries making an extensive use of gas is a long and impressive one," he continued. " It ranges from big engineering industries, ship building, and the manufacture of munitions, aircraft, and motor vehicles to the essential food manufacturing trades, and it enters into many almost unknown processes. It is hardly realized that gas plays such an important part." With which final sentiment we heartily agree.

Co-Operation with Ministry of Food

Demonstrators at Research Kitchens

Since the early seventies of last century, Messrs. R. & A. Main, Ltd., have grown to be well known in the Industry for the special service which they have rendered to the Nation in their research and development of the science of cookery and nutrition. In spite of the difficult times this work still goes forward, and a recent development took the form of interesting experiments in making pastry and other dishes, utilizing ingredients that are cheap and plentiful. These were carried out in the firm's special Research Kitchens by demonstrators from the Ministry of Food.

We have heard a great deal lately about potatoes, carrots, and oatmeal—three vital foods which have been somewhat neglected by the public hitherto, but which are not only home-produced, but lavish in supply. Housewives and caterers have been asked to make use of these foods, and the Ministry of Food demonstrators showed practical ways of using them as a basis to provide a variety of appetizing dishes. These were much appreciated by representatives of the general Press and other interested bodies who were invited to attend the subsequent exhibition at the Ministry of Food. It is difficult to imagine that the humble " spud " could ever be converted into the guise of the luscious éclair, but this is only one of the many ways in which the potato can be served.

The housewife's job, though always a difficult one even in peacetime we suspect, now calls for more skill than ever, and it is gratifying to note that the Gas Industry is continuing to do all it can to help her, as typified in the recent co-operation of Messrs. R. & A. Main with the Ministry of Food.

PIPE MATERIALS AND COATINGS*

By A. S. FITZPATRICK,

Chief Research Officer, National Gas Association of Australia.

THE first mains laid by the Australian Gas Light Company nearly one hundred years ago were of bare cast iron, and this practice was continued until about 1913, when steel mains, coated externally with coal tar pitch reinforced by hessian wrapping, were introduced. Some five years later both bare cast-iron pipes and wrapped steel pipes were laid in large quantities, the latter being used mainly for high-pressure trunk mains. There followed a gradual return to the use of bare cast-iron pipe until eight or nine years ago when, with the development of the centrifugal process, bare spun iron pipe came into use almost exclusively for mains up to and including those of 12 in. diameter. The spun pipe was supplied with wall thicknesses appreciably less than those of the sand cast pipe used hitherto.

For mains of less than 3 in. diameter, unprotected screwed wrought iron and mild steel gas pipe was used until about three years ago, when it was superseded by bare mild steel steam pipe, which, incidentally, had approximately 25% greater wall thickness. Latterly, the Company has reverted to the use of mild steel gas pipe, protected externally by means of cement mortar as described in detail subsequently.

Recently, numerous perforated cast-iron mains have been encountered ; in some instances these mains had failed within seven to ten years after having been laid. It is a significant fact that many of the corroded cast-iron mains referred to were of centrifugally spun iron. Notwithstanding the fact that the thinner wall of the centrifugally spun iron pipe would account for disproportionately shorter useful lives of such pipe as compared with those obtained from the thicker-walled sand cast-iron pipes, considerable local controversy has arisen regarding the relative merits of spun and sand cast pipe.

There have been indications that spun iron pipe is subject to more rapid corrosion than sand cast pipe. Accelerated laboratory tests indicated that spun pipe, when subjected to electrolysis, suffered a higher pitting factor than sand cast pipe. The tests indicated further that there was little difference between the two materials in so far as their resistance to soil corrosion was concerned. Pit depth measurements of pipes in service indicated that the spun pipe had a higher pitting rate than sand cast pipe. Neither the laboratory tests nor the field measurements can, however, be accepted as conclusive. Incidentally, it is significant that the city and suburban railway system was electrified about the same time as the Company adopted the use of centrifugally spun iron pipe, and it is possible that the Companies reticulation system generally has been subject to accelerated corrosion as the result of stray current electrolysis during the intervening period. Furthermore, as sections of corroded mains were replaced by spun iron pipe, the new metal, being in metallic contact with the old pipe, would become anodic, and for a time, at least, would suffer accelerated corrosion, which may have appreciably shortened its life.

In view of the Company's experiences with the corrosion of spun iron pipe, it has been deemed expedient to specify that the wall thickness of such pipes shall be the same as the standard for sand cast-iron pipe.

Wrought Iron and Mild Steel

Since no appreciable difference in the rates of corrosion of wrought iron and mild steel pipes has been experienced by the Company, the latter has been adopted as standard practice for service pipes on account of its lower cost. Two grades of mild steel pipe are employed by the Company—thick-walled or steam pipe for services which are laid without protective coatings, and thin-walled or gas pipe when used either underground, in conjunction with protective coatings, or above ground level.

The locally produced mild steel service pipe is manufactured from skelp by the butt weld process. Experience has shown that the weld seams of these pipes are frequently potential zones of rapid localized corrosion which is manifest as lines of pit holes. Consequently, in order to obviate as far as practicable early failures of service pipes as the result of defective welds, the Company has adopted the practice both of subjecting all mild steel pipes to a rigid visual examination, and of testing samples from each consignment in a machine which applies a standard impact to a tapered mandril inserted in the end of the pipe.

Experience having shown that exposed threaded portions of mild steel pipe fail very rapidly, the Company has adopted the use of thick-walled mild steel pipe for construction of " connectors " with long running threads. The thickness of the metal at the base of the thread of the connectors is equal to that of the wall of the pipe normally used.

Malleable cast fittings have been found to be more susceptible to corrosion than mild steel fittings, and their use for underground services has been discontinued.

Of the non-ferrous metals economically available for the distribution of gas, copper and lead offer the most promise. For the past ten years copper has been used extensively throughout Sydney and its suburbs for water services and has given excellent results, especially in the absence of stray-current electrolysis. For many years it was alleged that the use of copper for the distribution of manufactured gas entailed a serious risk of explosive acetylides forming as a result of interaction between constituents of the gas and the copper. However, doubts in this direction have since been dispelled and copper is being used in special instances for gas services, and is becoming increasingly popular for the supply of gas within buildings.

It is considered that when the stray current electrolysis hazard in Sydney and its suburbs has abated, the use of thin-walled copper tubing for gas services will probably offer the best means of combating soil corrosion of service pipes. Meanwhile, however, the Company is obliged to continue to use mild steel tubing either with or without protective coatings.

Flexible lead connexions between the cast-iron water mains and the galvanized wrought iron water service pipe were used in Sydney as standard practice until copper service pipes were adopted. An examination of a large number of such lead connexions, which had been buried for upwards of forty years, revealed that they were, in general, in an excellent state of preservation. The doubts raised in respect to copper, concerning the risk of failure as a result of stray current electrolysis, would be much greater, however, in the case of lead.

Lead is not affected by the constituents of gas and has, in fact, been used for many years for making flexible connexions to gas meters. Despite this fact, however, lead pipes are not regarded with favour, owing to the fact that they tend to sag and give rise to traps in which any condensate from the gas may collect, thereby interfering with the continuity of supply ; consequently, lead is not considered to be a satisfactory material for service pipe construction, at least until such time as the present electrolysis hazard has been mitigated, and until such time as the dew-point of the gas distributed by the Company is maintained below that of the lowest earth temperature, as is now customary practice in many gas undertakings.

While it is possible to increase the rigidity of lead pipe, either by increasing its wall thickness or by alloying it with other metals, such as, for example, antimony, neither of these alternatives is considered desirable in view of the added cost of the former and of the reduced corrosion resisting properties of the lead alloy.

Non-Metallic Materials

Of the various non-metallic substances which have been suggested for the construction of gas mains, asbestos-cement appears to offer the most promise. Pipes of this material have been successfully used for the past ten years in the reticulation of water in many parts of Australia where soil-waters are relatively free from carbon dioxide.

In view of the promising results obtained from asbestos-cement pipes, both in regard to their resistance to the corrosive effects of local soils and to stray current electrolysis, an investigation was undertaken to ascertain whether this material would be suitable for gas mains. The conclusions drawn in this regard were that although the mechanical strength of asbestos-cement pipes was somewhat inferior to that of cast iron, the disabilities of the former were not such as would seriously militate against their practical application for gas mains. Furthermore, in the absence of condensed moisture, the pipe

* From a survey of the problem and of recent investigations on Unaccounted-for Gas carried out by the National Gas Association of Australia. The results are published in a comprehensive Report of the Association.

was apparently not affected by the constituents of manufactured gas.

Further tests established that dry asbestos-cement pipe was definitely porous in so far as gas is concerned, but that when the pipe was fully saturated in respect to moisture (that is, when containing approximately 18% by weight of moisture), the pipe becomes impervious. These experiments were conducted with asbestos-cement pipe formerly available, a material of lower density than the " Eternit " type since developed.

The actual moisture content of asbestos-cement pipe buried in the soil is dependent upon the texture and moisture content of the soil in contact with it. Thus, for example, it has been found that asbestos-cement pipe will remain saturated with moisture when in contact with sands containing as low as 2% of moisture, whereas when buried in clay it is necessary that the clay shall contain 25% or more of moisture in order to ensure complete saturation of the pipe wall. In this regard it is interesting to note that the survey of the soil conditions existing in Sydney and its suburbs indicated that local soils normally contain sufficient moisture to maintain asbestos-cement pipe buried in such soils, saturated and impervious to gas. Later experience, however, raises a doubt as to whether this applies in all cases.

Having regard for the modern practice of distributing partially dehydrated gas, the dew-point of which is appreciably below ground temperature, it follows that moisture would be absorbed from the pipe surface by the gas. It is not possible to conjecture whether the rate of absorption of moisture would be such as seriously to re-saturate the gas on the one hand, or whether it would be such as would exceed the rate at which moisture would be absorbed by the pipe from the surrounding soil—a condition which would tend to dry the pipe wall and render it porous to gas. Investigational work along these lines is being carried out, and meanwhile the Company is refraining from using asbestos-cement for gas mains.

Pipe Coatings

Much research has been carried out all over the world during the last few years on pipe coatings, especially in relation to steel mains. The general consensus of opinion is in favour of a cut-back horizontal retort coal tar pitch priming coat, followed by layers of coke oven pitch, sometimes blended with true bitumens and often loaded with limestone dust to neutralize the tar acids. The use of hessian within the coat is eschewed, and a non-rotting fabric of asbestos is preferred. As much as possible of the coating should be done in the factory, but the joints between lengths of pipe necessarily have to be coated in the field. It is difficult in a small space to epitomize the vast literature now accumulating upon this subject ; but recent research clearly indicates that the coating and other protective devices required by steel mains are so expensive as to warrant a great use of cast iron instead, and the economic uses of steel pipes are considerably curtailed.

The steel mains laid by the Australian Gas Light Company some 23 years ago, to which passing reference has been made in the previous section, were protected with a relatively thin layer of coal tar pitch reinforced by a double ply of hessian wrapping applied by machine. This protective coating, in the course of a comparatively short period, failed, principally as the result of the rotting of the hessian reinforcement, especially on those sections of the main which were laid in damp clay soils.

Following the early breakdown of the protective coating, the relatively thin-walled steel main had a short useful life in comparison with that of cast iron. Consequently, since little difference existed locally between the cost of wrapped steel main and that of cast-iron main of similar diameter, a policy was adopted of replacing defective wrapped steel mains with cast iron. To enable gas to be distributed at high pressure to an outlying district, a welded mild steel feeder main, together with subsidiary mains and services was laid. These steel mains and services were enclosed in asbestos-cement troughing filled with coal tar pitch. Although it was considered that this would offer an ideal protection inasmuch as the pitch would effectively render the pipe waterproof and the trough would in turn protect the pitch from mechanical damage, the practical difficulties experienced in the application of the pitch coating considerably added to its cost and tended to militate against its effectiveness. The practical difficulties referred to were due to the molten pitch flowing along the inclined portions of the troughing and overflowing at lower levels, thereby leaving portions of the pipe, at the higher levels, unprotected. To obviate this tendency, it was necessary to fill the troughs in a more or less piecemeal manner which tended to render the cost of the protection excessive.

Some five years ago the Company laid a number of experimental lengths of mild steel service pipes pre-coated with a layer of cement concrete, having a minimum thickness of half an inch, and consisting of 1, 1½, and 1½ parts of portland cement, sand, and fine basalt screenings respectively. These services were laid simultaneously with, and adjacent to, a number of bare iron services at locations where experience had shown that severe corrosion would normally be encountered.

After a period of two years, several of each of these coated and bare services were removed for inspection. The bare pipes were found to be seriously pitted to a depth equivalent to half their wall thickness, while in the case of the coated pipes, the concrete was in excellent condition, and the underlying metal was in a perfect state of preservation except in one instance, where a defective field joint had been made around a screwed socket.

In view of the promising nature of these trials, the Company tentatively adopted the practice of protecting service pipes and mild steel mains with cement coatings, pending further developments in respect to the investigations being made into other protective coatings and into the stray-current electrolysis position in Sydney and its suburbs.

The cement coating is now applied to the mild steel pipe *in situ*—two distinct processes being employed according to whether it is necessary to excavate a trench in order to lay the pipe, or whether it is threaded under the roadway through a tunnel formed in the ground. In the former case the pipes are centred and supported on moulded cement blocks, within an asbestos-cement trough, and a 1 : 3 cement mortar is well grouted around the pipe.

A method developed by the Company's Mains Superintendent of applying cement mortar coatings to service pipes threaded through the ground is especially applicable in renewing defective service pipes which are usually withdrawn by means of a winch. The holes left in the ground after the removal of the defective pipe are enlarged in diameter by pulling bottle-shaped steel formers through them. New service pipes are threaded through the prepared earth tunnels with small supporting pieces attached to prevent sagging of the pipes. Fairly fluid cement mortar is forced along the annular spaces between the pipes and the soil by means of an injector. Originally the injectors employed for this purpose were fitted with one plunger only, and a suction effect was created when the plunger was withdrawn for the purpose of refilling the inlet pipe ; this difficulty has been satisfactorily overcome by the adoption of an injector having two plungers working alternately.

The experience of the Metropolitan Gas Company in relation to leakage of mains and service pipes has led to the conclusion that when all the mains are of cast iron laid in firm ground practically all of the leakage will occur on the service pipes, and it is the improvement of these that will reduce the unaccounted-for gas. Experience in the Australian Gas Light Company has shown, however, that the condition of main joints is probably the most vital factor in causation of leakage from mains and services.

It is interesting to note that in recent tests carried out under the auspices of U.S. Bureau of Standards it was shown that there was no marked superiority in the rate of corrosion of the various qualities of ferrous pipe materials such as mild steel, copper-bearing steel, puddled wrought iron, &c., except under special soil conditions. It was also shown that bituminous coatings could at best delay deterioration for only a few years. In the United States of America, where there is a relatively high price differential between steel and cast-iron pipe, in favour of the former, steel is used extensively for mains and services. A further recent tendency has been for a thinner-walled steel pipe to be used, the saving in price being applied to provide a higher quality of protective coating.

Leakage of service pipes usually commences with corrosion and perforation beneath the water tables. This portion of the pipe might well be initially wrapped with a protective coat and care taken to remove all ashes from contact with the pipe. It has been found good practice in Melbourne to lay pipes in sand when the ground is corrosive ; it preserves a more homogeneous environment for the pipe. But in recent tests of samples buried in some of Melbourne's worst soils, it was found that specimens which had been wrapped in filter paper before laying in many cases suffered more loss of weight than those buried directly in the soil. The depth of pitting was less, however. On the whole it was concluded that it would be preferable to lay the service pipes in sand when the soil was corrosive.

In Adelaide, too, it has been found that service pipes are generally corroded more under one or both water tables on the two sides of the road, whereas the section under the crown of the road is usually in a relatively good condition. In order to

minimize expense in replacement of perforated service pipes, the policy has therefore been to renew only the sections under the water tables.

Copper Service Pipes

Regarding copper service pipes, it is necessary to note that copper is cathodic to iron when immersed in soil fluids, and because of this, the Melbourne and Metropolitan Board of Works requires that an insulating joint should be installed to sever the metallic connexion between copper service pipes and steel water mains. Copper pipe has been adopted by a number of American gas undertakings, one of which has used copper for a period of nine years for services and for mains up to 3-in. diameter and claims it to be highly satisfactory. To guard against the possibility of galvanic corrosion being set up near the junction between the copper and the iron pipe this Company has always applied a protective coating to both pipes for a distance of 3 ft. on either side of the junction. Another American undertaking has used an insulating joint between the copper service pipe and the iron main.

Copper pipes could not be used for gas if ammonia were present. It is noteworthy that with dehydration by intense cooling when the gas is washed by chilled water, the gas is practically free from ammonia. The mutual effects of copper and iron in contact in various soils require further investigation.

In a Paper delivered in 1938 by F. A. Gaydon before the Australian Gas Institute an excellent summary was given of recent developments in the important subject of pipe joints. The section was as follows :

Joints are definitely the weak links in a pipe system and in very many cases are probably the greatest single factor contributing to the total leakage. Considering the fact that there may be anything from 300 to 500 joints in every mile of main, even minute average leaks from these would amount to a large annual figure. It therefore behoves engineers to pay special attention to this aspect of their systems and to adopt a satisfactory class of joint and, above all, to insist that a high standard of workmanship be maintained when making joints in the trench, as otherwise no type of joint, however well designed, can be expected to remain gas-tight.

The question of joints for gas mains has received a great deal of attention from the American Gas Association and its members during the last ten years, and the A.G.A. carried out a series of laboratory tests of the different types available, and made an exhaustive investigation of their value under service conditions. The final conclusions and recommendations of the Association are summarized as follows :

(*a*) Cement joints are not recommended for pressures much in excess of 10 in. W.G., and should be restricted, as far as possible, to the smaller sizes of pipe.

(*b*) Cast lead joints are not considered satisfactory for new construction, even for low pressures.

(*c*) Lead wool joints, while superior to cast lead, are quite expensive to prepare, and it is doubtful whether they can be depended upon to withstand service conditions. The objection to the use of cast lead applies to a certain extent to lead wool.

(*d*) The use of two concentric rubber rings, with inclined faces in contact and held in place by cement, is recommended for joints up to and including 16 in. in size, and for pressures above $\frac{1}{2}$ lb.

(*e*) Mechanical joints, such as the Anthony, Dresser, and Doublex Simplex, all of which make use of rubber rings as gaskets, are recommended for use with cast-iron mains for pressures above 25 lb.

These conclusions were published in 1932, and it is of interest to note the subsequent trend in the practices adopted by various American gas undertakings.

With very few exceptions, American companies have abandoned the use of lead joints for cast-iron pipe, even for low pressure distribution. Some few companies have replaced this class of joint by cement joints, or a combination of cement and rubber rings, while the great majority have adopted one or other type of mechanical joint.

Cement joints have been tried by several concerns, but abandoned for various reasons. On account of the extreme rigidity of the joints, frequent main breakages resulted, especially on the smaller sizes of main. On the larger pipes the cement is weaker than the pipes, and, if this should break, the leakage immediately becomes larger. A further objection is that a satisfactory joint of this nature requires considerable care in preparation, and should be allowed to cure for 24 hours before being subjected to the strains occurring in backfilling the trench.

The combination joint of rubber and cement requires the same careful attention in its assembly as does the cement joint, but it has the advantage that it is the rubber and not the cement which retains the gas. A precaution adopted by one of the undertakings using this class of joint is to paint the end of the spigot with a waterproof compound to prevent the cement, with which the joint is made up, from adhering to the spigot, thus giving the joint a stuffing box action and avoiding the rigidity of the cement joint.

Mechanical joints are generally of two main types : The gland type, using a special socket made integral with the pipe ; and the coupling type, using plain end pipe with a mechanical sleeve coupling. The inside of the socket in the one type, and the ends of the sleeve coupling in the other, are shaped to take rubber gaskets which are held under compression by follower rings bolted up behind them. The coupling type is used more commonly with steel pipe, but is also used in some cases with plain end cast-iron pipe. The main advantage claimed for pipe joints of this type is that they permit movement between wide limits while remaining perfectly gas-tight. From these points of view, the mechanical joint is undoubtedly the best available type, and is used extensively even for low-pressure distribution. It has certain disadvantages, however, chief of which is the danger of bolts corroding. This is not considered as a serious hazard by many users of the joints, as it is claimed that in practically all such cases found, either the follower ring was so held in by rust that no movement had taken place, or that the rubber gasket had formed a tight bond to the metal of the pipe, and no leakage occurred. On the other hand, some engineers take care to protect the joint by means of a bituminous or other waterproof compound. A further objection has been raised to these joints in the past, namely, that the rubber gasket tends to flow into the narrow space at the bottom of the socket, and so relieve the pressure on the gasket, and permit the pipe to leak. This trouble has been overcome in more recent years by an improvement in the class of rubber, and also in certain cases by the addition of reinforcement at the tips of the gasket, in the form of lead, cotton duck, or a bronze wire coil.

In this connexion it is of importance to stress the need for restricted tolerances on the sizes of the pipe with which these joints are used. For example, American tolerances for both spun and cast-iron pipe are that the inside diameter of the bell and the outside diameter of the spigot of pipes up to 16 in. diameter shall not vary from standard dimensions by more than 0·06 in. This, therefore, ensures that the clearance between socket and spigot will not vary by more than approximately $\frac{1}{8}$ in. On the other hand, the tolerances of the standard pipes available in Australia are appreciably greater than this. For both spun and sand cast-iron pipe, the tolerance on the external diameter of the spigot is plus $\frac{1}{8}$ in. or minus $\frac{1}{16}$ in., while that for the internal diameter of the socket is plus or minus $\frac{1}{8}$ in. Thus a total variation in the width of the annular space of $\frac{7}{32}$ in. may occur in this pipe, a figure which is nearly double that allowed on the American pipe. These wide tolerances are a disadvantage from several points of view, and the difficulties would be very great in attempting to adopt a satisfactory joint of either the combination cement and rubber or the mechanical type for use in this country. Closer tolerances would be necessary for either of these joints to be a success. After detailed investigations into various types of joint, the Australian Gas Light Company has developed one form of mechanical coupling, concerning the production of which negotiations are now in progress.

A somewhat new development in joining cast-iron pipe is the use of bronze welding. One company, for instance, laid an experimental length of two miles of bronze-welded pipe, one mile using an ordinary " V " weld, the other using the " Shear V " weld. The " V " weld joints resulted in 10% of breakage of the pipe close to the weld, while with the " Shear V " no case of breakage was found. Other companies also have carried out certain work in this direction, but many engineers fear that this class of joint is too rigid for cast-iron pipes.

Welding is probably the commonest form of jointing steel pipes, whether for mains or services, but for the latter, many companies still use screwed joints. One method adopted to protect against serious localized corrosion of the pipe at the threads of screwed joints is to use the long line recessed coupling, the recessed portions of the coupling which overlap the unused threads on the pipe being packed with red lead.

The mechanical coupling has been adapted also for use with service pipe, and has been used extensively by some companies. A more recent form of coupling devised for this purpose is the boltless compression coupling, the follower rings in this case taking the form of nuts screwed on to the sleeve of the coupling. This makes a particularly good type of joint, is easy to assemble, and obviates the necessity of threading the ends of the pipe.

A joint which will be gas-tight under almost any pressure can usually be made by screwing up the coupling by hand. This coupling can be used also as an insulating joint for connecting copper to iron pipe, in which case a thin rubber sleeve is slipped over the end of the copper pipe, the thickness of the rubber being such that its outside diameter is the same as that of the iron pipe, thus permitting the coupling to be used in the ordinary way.

Repairs to Pipe Joints

The American Gas Association, some years ago, conducted an investigation into the various methods of repairing bell and spigot joints. It was found that remaking the joint or recaulking, in the case of lead joints, was unsatisfactory, as was also the use of a rubber repair ring caulked into the socket without a holding clamp. Leak clamps were recommended as the only satisfactory method of repairing these joints.

American Gas undertakings, with relatively few exceptions, have subsequently adopted leak clamps of one form or another as the standard method of repairing bell and spigot joints. Some take the precaution before installing the clamp to face up the lead flush with the end of the socket, while others consider this is unnecessary. The Australian Gas Light Company has closely investigated the various types of leak clamps available, and in consequence has developed a type of leak clamp which it is expected will be suitable for Australian conditions.

As an alternative to leak clamping, some undertakings, especially whose who have changed from a moist manufactured gas to a dry natural gas, adopt some form of gas conditioning, such as oil fogging or rehydration. Either method tends to maintain the jute packing of the joints in a saturated, and therefore somewhat swollen condition, and so prevents leakage to a great extent. The method is claimed to have the added advantage that it restricts dust troubles to a minimum. A smaller means which has frequent application in treating sections of the main, is the addition of certain liquid compounds which are designed to saturate the jute packing. Two trade preparations are available for this purpose. None of these methods can have much effect if the gas is already wet, or if the jute packing in the joints has deteriorated.

One undertaking has devised a means of leak-proofing a bell and spigot joint by casting around it a mass of concrete. Before placing the concrete, a small perforated copper tube is placed around the face of the joint, and, after the concrete is set, a soap solution is forced into the tube under high pressure, and this is claimed to provide a sealing action by the formation of plastic, sticky substances which fill the pores of the concrete. The method is, no doubt, effective, but its application seems costly.

Benzole Recovery and Rubber Joints

Where rubber jointing material is employed in distribution systems, the adoption of benzole recovery may lead to an immediate increase in losses through pipe joints. In view of the possibility that Australian gas undertakings may be encouraged to consider the recovery of benzole during wartime, it is of interest to note the experiences of overseas undertakings in this connexion.

M. Brabant (" The Question of Rubber Joints," *Journal des Usines a Gaz*, Jan. 20, 1935) stated that when in 1929 gas totally freed from benzole and naphthalene was introduced into certain Belgian gas distribution systems, losses rose within a very short period to " catastrophic figures—up to 25, 30, 40% and even more, of the total output." Investigation showed that this was due to the absorption of benzole from the rubber joints, leaving them smaller, less elastic, and permeable to gas. It was shown that under the action of gas containing benzole, rubber expands considerably, and becomes more flexible ; the tightness of the joint is maintained as the rubber does not dry or contract. Deprived of the benzole by the passage of gas freed from this substance, rubber ceases to give gas-tightness to the joint.

The Belgian investigations also showed that new rubber, which had never been subjected to the action of benzole, was not affected by gas freed from benzole. The most effective means of restoring gas-tightness was, therefore, to disconnect the pipes and replace the faulty rings with new ones. On account of the cost involved and the necessary interruption of service, this course was not adopted generally ; the defective joints were made tight by means of lead wool, " Denso " material, cement, and asbestos yarn. New pipelines were linked up by specially contrived joints in which similar packing material and also a plastic substance known as " antibenzole " were used.

These remedies had the disadvantage that flexibility of the pipeline was lost. For this reason, certain Belgian undertakings endeavoured to find a type of rubber which would not be affected by benzole. Experiences in this connexion are described by M. Bastien (*Journal des Usines a Gaz*, Sept. 20, 1935), who states that the gum content of the rubber, and its freedom from tension when fitted, are most important. Investigations into the problem of rubber joints and substitute materials have been carried out by the Gas Industry in France and in Germany.

THE INSTITUTION OF GAS ENGINEERS

SECOND ARTHUR DUCKHAM RESEARCH FELLOWSHIP REPORT

The Radiation from Solid Substances Under Flame Impact: Part 1*

[Communication No. 237]

I SUMMARY

The emission of radiant energy from the products of combustion in gas flames represents only a small part of the total energy of combustion; on this account, whenever such an emission is desired, whether for light production or radiant heat, it is customary to use as the emitting source a solid body heated by flame impact.

It has been generally assumed, and in some cases proved by experiment, that in all cases such solid bodies emit in accordance with the laws of thermal radiation; thus, in particular (i) the emitting surface is raised to a temperature which may approach but can never equal that of the flame; (ii) the quantity of radiation of a given wave-length emitted is given by the product of the emissivity of the body concerned and the quantity of radiation emitted by a " black body " at the given wave-length and temperature.

The work of E. L. Nichols and his co-workers in recent years at Cornell University has suggested, however, that there are certain substances which, when in contact with flame, emit visible radiation in excess of that given in accordance with the above laws of thermal radiation. This excess radiation is defined as " luminescence ". It has been claimed, for example, that (*a*) in some cases these substances, when heated to incandescence, show a luminescence which supplements the normal thermal radiation, and (*b*) in some cases visible radiation is emitted when the bodies are at a temperature below that at which thermal radiation can be emitted, i.e., the radiation is all luminescent in character. The latter effect (*b*) has also been noted by certain German investigators.

In this Report, following a consideration of the application of the laws of thermal radiation, it is emphasized that the production of light by means of a thermal radiator heated by a gas flame can never be other than a relatively inefficient process. If a high efficiency is ever to be attained the actual production of luminescent radiation is essential, and the possibility of this is discussed in the light of recent developments in physics and chemistry.

A critical survey of the literature of the subject bearing on the apparently anomalous emissions from certain materials has been given, and inconsistencies and difficulties in the experimental evidence are pointed out.

A repetition of the experiments of Nichols in case (*a*) above has confirmed his observations, but when the temperature of the emitter was determined by using very fine thermocouples, it was shown that the assumptions made in the interpretation of the results are unsound; there is no evidence that any radiation is emitted which is other than purely thermal in origin. At the same time, the behaviour of such substances shows abnormalities which suggest changes in the emissivity

* The work involved was carried out at Leeds University.

of the bodies under the experimental conditions not hitherto recorded. This aspect of the subject will be investigated further by means of infra-red spectrometry; in addition to the issues referred to, the matter has a bearing on the design of radiators for heating processes.

The luminescence observed from surfaces in contact with flame at temperatures below incandescence, case (*b*), has also been the subject of investigation. While it was claimed by Nichols that this emission was obtainable with a number of pure substances, the German workers found it only when some impurity, a so-called "activator", was present in the crystal lattice. The latter observation has been confirmed, and the luminescent nature of the emission now placed beyond question by means of spectrographic evidence. A number of new luminescent substances have been discovered and the importance of the proportion of an activator made clear; there is, in fact, a critical concentration of "activating" material in any particular instance for the optimum production of luminescence. The essentials of the mode of supporting the substance for maximum light efficiency have also been considered.

The quality of the emitted light has been the subject of spectrographic investigation. It is suggested that although the practical application of these substances to light production presents difficulties, the subject merits further study both from the practical and theoretical standpoints, and the nature of future work is discussed.

II INTRODUCTION

The products of combustion of an aerated gas flame are essentially poor radiators, and hence for the production of radiant emission, whether in the infra-red or visible region of the spectrum, it is customary to utilize as the radiant material a heated solid body having suitable physical properties. In a non-aerated flame, carbon particles serve as radiant emitters, but the temperature attained is relatively low and while the overall radiant efficiency is of the order of 10 to 20 per cent, depending on conditions, that for the visible radiation is something like 0·04 per cent.

In so far as the solid radiators used in gas appliances for radiant heating are concerned, it appears to have been universally accepted that the radiation emitted is purely thermal in character, i.e., it is subject to the laws of thermal radiation enunciated by Kirchoff. On the other hand, when the Welsbach mantle was first applied to light production there was considerable controversy as to whether the emission was in accord with these laws, or whether some kind of "luminescent" phenomenon was involved. The work of H. Rubens in 1905-6,[1] however, produced an explanation of the relatively high efficiency of the thoria-ceria mixture, and showed that the emission was purely thermal in character within the limits of experimental determination. This result was confirmed by H. E. Ives, E. F. Kingsbury and E. Karrer[2], who also made an extensive survey of gas mantle materials and construction, and derived an upper limit for their light efficiency with attainable materials.

There appears to be no reason to doubt the accuracy of this work and it implies, as has been recently pointed out by L. T. Minchin, A. B. Densham and J. Wright[3], that so long as a radiant material in thermal equilibrium with the hot products of the flame is used as a light source, there is no prospect of a drastic increase in the efficiency of light production from gas, or any increase in any way comparable with that now obtained from the modern electric discharge lamps, the efficiency of which now approximates to some ten times that of the ordinary gas-filled tungsten lamp. This very high efficiency has been obtained by making use of the phenomenon of luminescence in one form or another.

This fact, and the increased interest in luminescent phenomena, have led to discussion of the possibility of the application of such phenomena to light production from gas, for in recent times there have been certain investigations which suggest that some substances, when in contact with a flame, emit radiation in excess of that given in accordance with the laws of thermal radiation. This work has been summarized admirably by Minchin.[4] Before considering the present state of knowledge in this subject, however, it may be of advantage briefly to recapitulate the laws of thermal radiation in so far as is necessary to define the terms and quantities involved and to include a discussion of modern views on the conception of thermal equilibrium and temperature.

III THE LAWS OF RADIATION

The intensity of radiation R_λ of a given wave-length λ emitted by a body at a temperature T°K. is given by

$$R_\lambda = E_\lambda - f(T) \quad \ldots\ldots(1)$$

where E_λ is the emissivity of the body at the wave-length λ. This quantity $E\lambda$ is exactly equal to $A\lambda$, the absorptivity at the wave-length λ, which is defined as the fraction of the incident light of wave-length λ absorbed by the body. $A\lambda$ can in no case be greater than unity and hence $E\lambda$ cannot be greater than unity. A perfectly black body is defined as one for which $E_\lambda = 1$ for all values of λ, and such a body will by definition also absorb all the radiation, of any wave-length, as follows:

$$f(T) = K_\lambda \left(e^{\frac{-C_2}{\lambda T}} - 1 \right) \quad \ldots\ldots(2)$$

where $K\lambda$ and C_2 are constants.

Hence the value of $f(T)$ for a "black body" may be determined at any particular temperature, and if the absorbtivity of any other body for a particular wave-length be measured at the given temperature, R_λ, may be determined similarly by multiplying by this absorbtivity, which, as stated above, is numerically equal to E_λ in expression (1).

This is a fundamental law, to which no exceptions are known. It forms the basis of several methods of measuring temperature, and may in fact be used to define the absolute temperature scale. On the other hand, it is common knowledge that radiation is emitted by many systems, as when undergoing chemical reaction, or under the influence of light or an electric field, which is greatly in excess of that given by this expression for their measured temperature. This does not constitute a departure from the law, as such systems are not in thermal equilibrium. It is customary to refer to these systems as luminescent, and luminescence may be defined as radiation emitted by a body in excess of that given by expression (1) above.

Returning to expression (2), the radiant energy of any wave-length emitted by a "black body" may be determined at any particular temperature, i.e., spectral distribution curves of the form shown in Figure 1, may be constructed

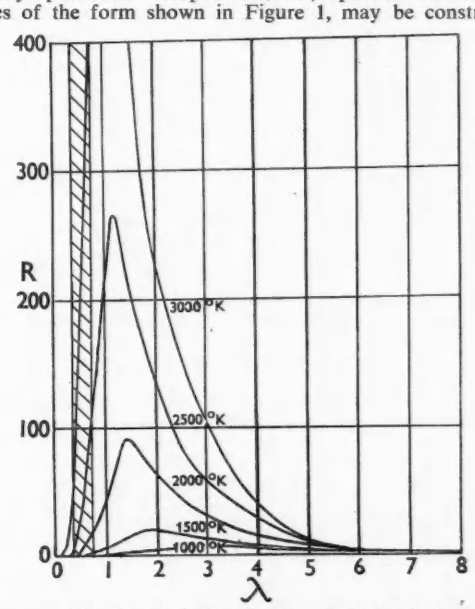


FIGURE 1.—*The Spectral Distribution of the Radiation from a Black Body at Various Temperatures. The Quantity of Radiation R (in arbitrary units) is plotted against the Wave-Length (in μ). The cross-hatched area represents the Visible Spectrum.*

for a number of temperatures. Now the eye is only sensitive to radiation from about 0·36 to 0·75μ, and inspection of the curves shows that the energy emitted between these wave-lengths represents only about 0·01 per cent of the total radiant energy for the body at 1,000°K., 0·08 per cent at 1,500°K., 0·3 per cent at 2,000°K., 0·7 per cent at 2,500°K. and 1·2 per cent at 3,000°K. This, then, represents a primary theoretical limitation to the use of any "thermal"

emitter as a source of visible light. As the eye is not equally sensitive to all colours within the region of the visible spectrum as defined above, in determining the practical efficiency of any light source it is necessary to correct for this, i.e., the energy emitted at such particular wave-length must be multiplied by the appropriate factor proportional to the sensitivity of the eye at that wave-length, or, alternatively, the energy must be measured after passing the light through a "spectral luminosity filter" which is arranged to make this correction automatically. In the case of electrical heating, the temperature of the emitter is limited by the physical properties of the material available. Using gas as a fuel, the upper limit is set by the temperature of the flame.

In point of fact, however, any substance in contact with a flame which is radiating energy at a rate greater than that of the flame gases, will never attain the temperature of the flame. Assuming an isolated particle in the flame, the actual temperature will depend on the relative rates at which energy is received by the particle, by conduction, convection and radiation, and the rate at which the energy is radiated away. In the case of any body having properties approximating to those of a "black body" the actual temperature attained will be far below that of the flame gases. There are, however, a large class of substances known generally as "selective" radiators, for which the spectral energy distribution curve shows little relation to that of a black body. Such substances still obey the fundamental laws which are involved in the expressions (1) and (2), but the factor E_λ is very different from unity for particular wave-lengths. Thoria is such a substance, its distribution curve at 2,000°K. being illustrated in Figure 2. The total energy

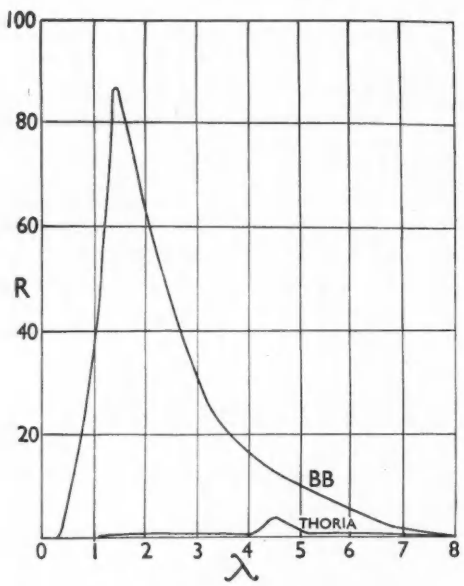


FIGURE 2.—*The Spectral Distribution of the Radiation from a Black Body and from Thoria, each at* 2,000°K.

radiated by thoria, as given by the area under the curve, is very much less than that of a "black body" at the same temperature. Hence, if a piece of thoria is placed in a flame, the temperature which it will attain is obviously very much greater than that of a similar specimen of a "black body".

Unfortunately, inspection of the curves also shows that the value of E_λ is very small indeed in the visible region of the spectrum, so that the particle of thoria, although it will get much hotter than the "black body", will still give out very little light. If a substance could be found which had values of E_λ approaching unity in the visible region, but very low throughout the whole of the infra-red, this would constitute the ideal mantle material, since it would approach closely to the temperature of the flame gases. Even then it would not be a particularly efficient means of converting the chemical energy of the combustion of the gas into visible light, since it would still radiate less than a black body at the given temperature, i.e., if the temperature attained were 2,000°K., closely approaching that of the ordinary low-pressure coal-gas flame, the radiant efficiency in the visible region would be only 0·3 per cent.

In practice no such substance is known, but an approximation to it is obtained by taking a mixture of ceria and thoria. Ceria, when hot, has values of E_λ approaching one in the yellow-green part of the spectrum, but the values in the infra-red, particularly around 4·5μ are also high. Hence, although it is an efficient radiator in the visible region, it will, like the black body, not approach to the temperature of the flame. By mixing ceria with thoria, however, in suitable small proportion, a compromise may be effected and a material obtained which approaches the temperature attained by pure thoria, but at the same time emits fairly well in the visible region. If too much ceria is added, the radiation in the infra-red will become greater, with consequent fall in temperature, and a point will be reached at which the output of visible light begins to diminish. The Welsbach mixture is that of optimum composition, and it has been used almost exclusively for the purpose of gas lighting for the past forty years.

In the light of recent developments in physics and chemistry, consideration may now be given to the possibility of obtaining much greater light efficiency from a given amount of chemical energy by using luminescent properties in some form or other. If we consider a gaseous system which is in thermal equilibrium, then according to the kinetic theory of gases, the temperature of the system is measured by the average random kinetic energy of the gaseous molecules, the velocities of the individual molecules being distributed according to the Maxwell-Boltzmann distribution expression:

$$dN_c = N_o \frac{4}{\sqrt{\pi}} \left(\frac{M}{2RT}\right)^{\frac{3}{2}} . e^{-\frac{C^2M}{2RT}} . c^2 . dc$$

N_o = number of molecules per c.c., M = molecular weight, R = the gas constant, T = the absolute temperature, dN_c = number of molecules having velocities between c and $c+dc$.

It is known, however, that when gases undergo exothermic chemical reaction, the energy which is liberated does not in all cases immediately appear entirely as an increase in this random kinetic energy of the molecules of the system. Part of the energy may be used up in raising the potential energy of some particular species, and a finite time may elapse before this energy is either given out directly as radiation, or "degraded" to normal thermal energy of agitation of the molecules generally. This may happen in several ways; among them are the raising of the molecule to higher rotational, vibrational or electronic energy states, or the formation of a molecule or atom which is physically stable but chemically unstable, i.e., it is capable of undergoing further exothermic chemical reaction. If an attempt is made to measure the temperature of a gaseous system containing such species, the value obtained will depend on the method used, i.e., whether or not the measuring instrument can interact with the "hot" molecules or unstable species concerned. As one simple example, if a stream of hydrogen at low pressure is passed through an electric discharge, or over a heated tungsten wire, then the resulting gas contains a proportion of free hydrogen atoms. If two ordinary glass thermometers are inserted into the gas stream, the bulb of one being "poisoned" by an adsorbed film of water, and the other closely surrounded by platinum foil, then the temperatures indicated by the two thermometers will be different. Hydrogen atoms do not re-combine on a glass surface on which water vapour is adsorbed, but platinum promotes the re-combination and hence the heat liberated, corresponding to the reaction

$$2H \rightarrow H_2 + 100{,}000 \text{ cal.}$$

is imparted to the second thermometer. The recorded difference in temperature will, in fact, be a measure of the concentration of hydrogen atoms in the gas.

Applying these considerations to the problem of obtaining greater luminous efficiency from the combustion of ordinary fuel gases, certain points are evident. It is not known to what extent the radiation from normal flames is chemiluminescent, but it appears certain that the emission of some lines from the flames containing salt vapours is greater than can be explained on purely thermal grounds[5]. The gas phase reaction between sodium vapour and chlorine, investigated by M. G. Evans and M. Polanyi, has been shown to have a luminous efficiency of about 30 per cent, but there appears no obvious way of increasing the radiating efficiency of the products of combustion of normal fuel gases.

On the other hand, it is known from spectroscopic evidence that various chemically unstable species, such as the radicals CH, OH and C_2 are present in coal-gas flames, and modern views of the mechanism of combustion suggest that oxygen and hydrogen atoms, and other radicals such as CH_2, CH_3, CHO, whose presence has not yet been demonstrated spectroscopically, have a transient existence in the reacting system. The work of W. T. David and his co-workers[7] on the temperature attained in gaseous explosions, seems to constitute a proof of the existence of some form of "latent energy" in the system, i.e., of "ordered" heat, energy resident in "hot" molecules or chemically-active species, which does not at first appear as normal kinetic energy of the product molecules. Again, little is known even now of the mode of transfer of the energy of chemical reaction from the interacting molecules to those surrounding them. The possibility that part of this energy is at first radiated at very short wavelengths, i.e., in quanta of very high energy, and absorbed by the surrounding molecules, has been suggested, but experimental proof or refutation of this hypothesis has not been forthcoming.

Here then would appear to be the basis of any possibility of obtaining greater luminous efficiency from the combustion of gas. It is necessary to find some substance which can interact with the "ordered" energy resulting from the elementary chemical reaction, before this energy is "degraded" to kinetic energy of the product molecules as a whole.

IV HISTORICAL

The first observation of the phenomenon which is now described as "candoluminescence" seems to have been by W. H. Balmain in 1842[8]; he prepared boron nitride and noted that this substance emitted a green radiation when in contact with the edge of a flame, although the surface was apparently below red, but the heat significance of the observation does not appear to have been realized until 1913, when J. Donau[9] repeated the experiment and found a similar result with certain specimens of calcium oxide. It was suggested that the emission arose from some form of oxidation-reduction process.

F. Paneth and E. Winternitz[10] showed that boron nitride was luminescent up to a bright red heat, and that some degree of heating of the material was necessary, this heat being either supplied by the flame itself or by the external electrical heating. E. Tiede and H. Buscher[11] also examined the luminescence of boron nitride, and showed that it was excited by a number of flames other than that of hydrogen, and also that it was brightest in the edge of the inner cone of a hydrogen-air flame burning in a separator. It was also shown that a similar phenomenon is observed with zinc sulphide and willemite, and it was stated that the luminescence from these substances could still be observed when a thin sheet of fused silica was placed between the material and the flame. Tiede and H. Thomaschek[12] showed that the luminescence of boron nitride was dependent on its crystalline structure, and that it was possible to prepare a very pure specimen of this substance which showed very little luminescence. The addition of a small proportion of carbon produced a strong emission. The spectral distribution of the radiation from boron nitride either under flame impact or under the influence of cathode rays was shown to be similar. In a later paper[13], an extension of this work was described by the same Authors, and the spectra of the luminescence excited by ultra-violet light, cathode rays and the hydrogen flame was compared. It was also shown that variation in the proportion of the activating carbon in boron nitride resulted in a change in the relative intensities of the emission bands observed.

Apart from the work here described, almost all the observations relevant to this phenomenon are due to E. L. Nichols and his co-workers at Cornell University. This work is described in a long series of papers published since 1921, those up to 1928 being collected together as a part of the Carnegie Institution Publication No. 384[14]. The first of these papers[15], forming chapter VIII of this publication, described observations on lime from various sources, and the oxides of zirconium, magnesium, silicon, aluminium and zinc, together with certain sulphides, including some of the Lenard and Klatt type, and certain miscellaneous substances such as white sapphires, corundum, synthetic ruby, calcite, fluorite, kunzite, topaz, boric acid, telluric acid, cadmium, phosphate, calcium carbonate, calcium sulphide, and zinc sulphide. All these were found to show some luminescence, while a list of inactive substances included the oxides of copper, lead, iron, nickel, manganese, cobalt, cadmium, tungsten, bismuth, antimony, barium, strontium, erbium, cerium, lanthanum and thorium, material from a Welsbach mantle and a Nernst filament, fused quartz, calcium tungstate, etc. The oxides were thinly coated on the surface of a copper block which could be heated independently, and a small "soft" oxy-hydrogen flame allowed to impinge on the surface of the oxide. It was assumed that if the layer of oxide were sufficiently thin, then its temperature was the same as that of the copper block, which latter could be conveniently measured by a copper-platinum thermo-junction in the surface.

It was found that the luminescence was visible only over a particular temperature range, characteristic of the substance concerned, in general lying between 0 and 700°C., but in some cases extending to 1,000°C. Experiments were also described which show that only the outer portion of the reducing zone of the flame was effective, that only the pure hydrogen flame—and to a lesser degree flames containing hydrogen—caused the luminescence, while the flames of alcohol, ether and carbon disulphide were definitely inactive. It was found that a strong electrostatic field had no effect on the glow. The light from a mercury discharge tube, even when the material was placed inside the tube, produced no luminescence in many substances which were active in the flame. It was further shown that the luminescence was not produced when hydrogen or oxygen, or a mixture of the two, was passed over the substance at red heat, or when the material was placed in a stream of atomic hydrogen from a discharge tube. It was concluded that the effect did not depend on traces of activating elements, although these might modify the luminescence, or even inhibit it altogether. An alternating oxidation-reduction process was suggested as the most probable mechanism.

The next chapter of the Carnegie Institution Publication consisted of two papers by E. L. Nichols and H. L. Howes[16], describing the photo-luminescence of flames containing solid salts. Various small changes in the intensity distribution of emission lines or bands in the flame when exposed to the radiation from a similar flame were noted.

An account of an extension of the investigation to a study of the radiation from incandescent solids was given in a subsequent paper by Nichols and Howes[17], forming chapter X of the publication. The experimental technique was to place the substance under test side by side with uranium oxide on a refractory support and to heat the two by a symmetrically disposed oxy-hydrogen flame. The temperature of the uranium oxide surface was determined by observation through an optical pyrometer, using the usual red screen. It was assumed that the substance under test was actually at the same temperature, while its apparent temperature was observed through the pyrometer, using a screen of any desired colour. These apparent temperatures then served as a measure of the brightness, I_O, of the surface at the particular wave-length passed by the screen. The brightness of the black body for the particular temperature and wave-length, I_{BB}, was calculated from the expression (I) given on page 7. The ratio I_O/I_{BB} was then plotted against the temperature. It was claimed that for many substances this ratio passes through a maximum, which may be 5 to 10 units, or even more at certain temperatures in the range 1,000 to 1,500°C. The oxides of magnesium, calcium, aluminium, beryllium, silicon, zirconium, zinc, germanium, gallium, samarium, gadolinum, titanium, neodymium, cerium, praesodymium and erbium, were all stated to show maxima of this type. The curves given for the praesodymium oxide, reproduced in Figure 3, are more or less typical of the behaviour of the other substances.

Experiments were also described which show that the radiation is subject to a fatigue effect. Figures were quoted for magnesium oxide viewed through the blue screen (wavelength 0·45μ) and it was stated that while 0·3 sec. after ignition the ratio $I_O/I_{BB}=65{\cdot}3$, after heating for some minutes the value became less than unity. A parallel was drawn between this behaviour and the necessity for rotating the cylinder of a limelight, and attention was drawn to the great intensity of the magnesium flash, where the oxide is formed in the nascent state. The effect of previous heat treatment was also discussed.

(To be continued in a forthcoming issue)

New Carburetted Water-Gas Plant

Five Million Cubic Feet Per Day

A CERTAIN Scottish town (which must be nameless) has always been in the forefront as regards the high efficiencies of public services and their Gas Department is no exception. Striking progress in its manufacturing and distribution departments is apparent to all who are qualified to judge.

The manufacture of carburetted water-gas is not new to this Gas Department as the first water-gas plant was installed at one of its Gas-works in 1918 by Humphreys & Glasgow, Ltd., the builders of the new plant just completed. This firm has also a plant in daily operation at another of this same town's Gas-works.

The new plant represents the latest development of the H. & G. completely automatic plant, about 200 examples of which have been installed in various parts of the world.

The main features of each of the two sections of the new plant are that they are self-operating, self-charging, self-steaming, and incorporate the makers' three-phase cycle back-run process and their latest system of automatically controlled secondary and tertiary combustion.

Narrow gauged trucks are used to bring coke for the plant to an underground receiving hopper, which discharges into a Humphreys-Glasgow patent traversing skip hoist which raises the coke to the necessary height and thereafter conveys it to a previously selected hopper. The coke in the overhead storage hopper is delivered by gravity down a chute incorporating a "cascade" coke screen to remove breeze, to the hydraulic charging and distributing machine mounted on the generator.

Self-Clinkering and Steam-Producing Generator

The self-clinkering and steam-producing generator may be considered as being in two parts, the stationary portion and the rotating ash-pan and grate. The stationary portion, which is supported quite independently of the rotating portion upon four massive columns, is also in two parts, the upper part being lined with fireblocks in the usual manner, and the lower taking the form of a low pressure annular boiler which surrounds the clinker forming zone of the fuel bed, and presents to the molten clinker, which often adheres to and builds up upon firebrick walls, a perfectly smooth and relatively cool surface, thus ensuring its regular descent to the self-clinkering grate.

The conical grate is mounted upon a heavily constructed cylindrical drum designed to crush the clinker masses into pieces of size suitable for easy discharge, and both are mounted upon and rotate with the large water-sealed ashpan. A stationary plough effects the continuous discharge from the generator of all ash and clinker to the small rail wagons provided for its reception, this generator refuse being effectively quenched before discharge by passage through the water seal. As a result no labour other than that required to change the clinker wagons is necessary to keep the generator fire in the best condition for gas-making.

The generator is directly connected with the carburettor by means of a firebrick lined conduit containing the secondary air blast diffuser which intimately mixes the secondary air with the combustible blast gases leaving the generator, the secondary air being correctly proportioned to the varying quantity of combustible in the blast gases by means of a special proportioning device operated and controlled by the automatic operator.

The carburettor is a steel shell lined with fireblocks and non-conducting lagging, and is partially filled with special checker brickwork which is maintained at the temperature most suitable for the proper gasification of the enriching oil.

The superheater with which the carburettor is directly connected is generally similar to but taller than the carburettor. A suitable offtake pipe for the carburetted gas produced connects the superheater top with the washer, while the hot blast-gases pass through a large firebrick lined conduit from the superheater to the waste-heat boiler. This conduit is provided with a shut-off gate for isolating the boiler when required for cleaning in which event the blast products pass to atmosphere through the stack valve and smoke stack above the superheater.

The vertical fire tube waste-heat boiler is of the latest type recently developed by the makers, and utilizes the sensible and latent heat in the waste blast-products for the efficient production of high pressure steam for use in the auxiliary machinery.

A patent "Centriflovane" grit catcher mounted on the waste-heat boiler smoke stack removes grit from the blast products issuing from the plant.

With the back-run process steam is admitted during part of the gas-making cycle at the top of the superheater, and passing backwards through the heated checker brickwork of the two fixing vessels enters the top of the generator in a highly superheated condition, the resulting back-run gas being conveyed directly from the base of the generator to the washer through a special connexion.

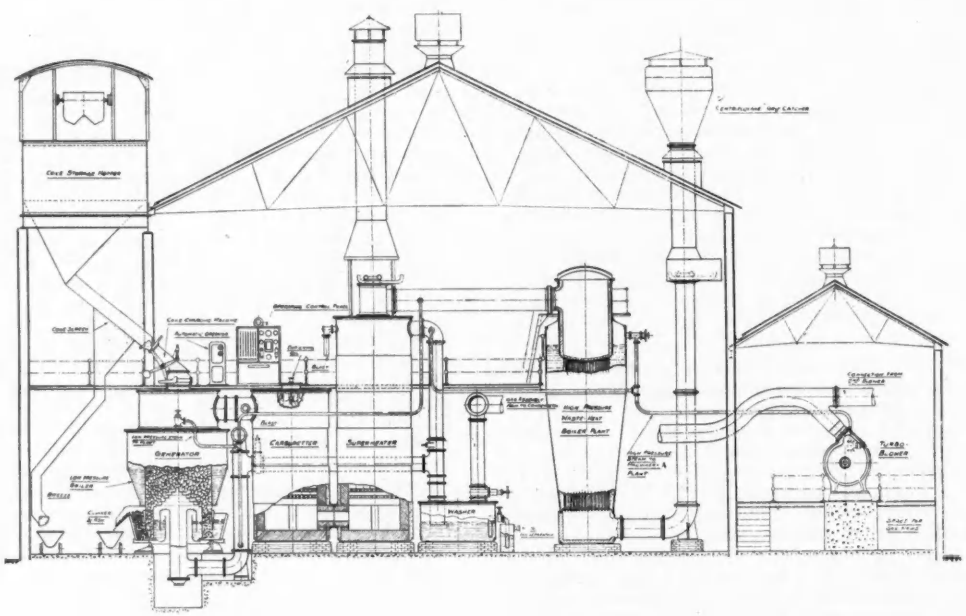
The back-run process returns to the fuel bed for use in gas-making, heat which would otherwise leave the generating plant with the gas and blast products ; it thus effects considerable savings in fuel consumption and, in addition, increases the capacity of the plant and greatly facilitates the control of temperatures throughout the apparatus.

The Automatic Operator

The automatic operator is an electrically driven machine which, by means of adjustable cams working in conjunction with the necessary mechanism, opens and closes at the required intervals hydraulic pilot valves admitting hydraulic pressure to the cylinders actuating the various working valves of the plant. The necessary hydraulic power is supplied at a pressure of 500 lb. per sq. in. by plant specially installed for the purpose.

The following nine valves are in normal operation worked once each cycle by the automatic operator : (1) Generator blast, (2) secondary air blast, (3) tertiary air blast, (4) stack, (5) steam, (6) back-run, (7) oil, (8) coke charger inlet gate, (9) coke charger discharge cone.

The timing of the valves is readily adjustable to all requirements, and by means of easily accessible gear certain of these valves can be disconnected at will from the operating sequence without the necessity for stopping the operation of the plant, thereby affording complete flexibility of control.



Probably the most important feature of the automatic system is the safeguard against possible irregular movement of the operating valves. In the event of any working valve failing to complete its proper movement or moving too slowly, the gas-making cycle is stopped and all valves, except that which has failed, are immediately brought to their safe normal position and at the same time the plant supervisor is notified by audible and visible signals of such shutting down. Similarly, the plant is shut down and the supervisor warned should the electric current or the hydraulic pressure supply fail ; in the latter case a sufficient reserve of pressure water to enable the set to be brought to the safety shut-down position is provided by a special hydraulic accumulator.

The provision of the above-described safety feature, the elimination of all manual labour, and the necessity for constant attention to time-keeping, makes it possible for one gas-maker to operate two or even three of these automatic plants, thereby greatly reducing the labour charges of the process. A mechanical counter records the number of gas-making cycles completed.

The blowing plant comprises two fan type blowers, one driven by a DeLaval steam turbine, and the other by an electric motor.

Feed water is delivered to the annular boilers of the generators and to the waste-heat boilers by Weir feed pumps located in the engine room, and is heated by means of a "Royles" exhaust steam feed water heater which utilizes the exhaust steam from the machinery.

The complete automaticity of the plant which reduces fatigue, labour and charges to a bare minimum, and the high efficiency in gas production resulting from the makers' new processes, effect striking economies in the cost of gas manufacture, and it will be appreciated by all who inspect this installation that carburetted water-gas manufacture has been revolutionized and water-gas costs must now be considered on a completely new basis. Moreover, it is of interest that Humphreys & Glasgow, the makers of the new plant, state that they have extended automatic operation to their plants of even the smallest capacities, and there are now water-gas plants in regular gas-works operation having daily capacities ranging from 70,000 cu.ft. of gas up to 6,000,000 cu.ft. per unit.

Sixty-two Years of Gas Appliance Manufacture

This year of 1941 marks the Jubilee of the Davis Gas Stove Company, Limited, which was registered as a private company in 1891. The Davis connexion with the gas appliance industry, however, dates considerably further back than this, the original gas stove manufacturing business of H. & C. Davis & Co. having been started in 1879 by Mr. Henry Davis, father of Mr. Cyril G. Davis, Chairman and Managing Director of the Company, and grandfather of Mr. Kenneth N. Davis, Joint Managing Director.

Roof Spotter Alarm Systems

Roof spotting has created the problem of transmitting suitable signals to the people "down under," and Londex, Ltd., Anerley Works, London, S.E. 20, have provided one solution. As the fundamental parts can be built together like toy bricks, alarm plants for small or very large factories can be easily installed. The Londex system consists of one or two delayed action push buttons mounted within easy access of the spotter. As soon as one of these is pressed an alarm circuit is closed for a predetermined time, from 10 seconds to 2 minutes, and it is not necessary for the spotter to remain exposed to danger. When imminent danger has passed, the second button is pressed, say for three short rings, enabling the employees to resume normal work. In the case of large premises, such as gas-works, where a simple bell should give place to several audible and/or visible alarms, the push buttons can be used to control small Londex relays installed in all the positions where the alarm has to be given, and sirens with up to 50 amps. consumption can be controlled. The circuit and alarm devices can be operated either from the electric mains or from an auxiliary supply to render the whole system independent of mains failure.

Half-Price Book Offer

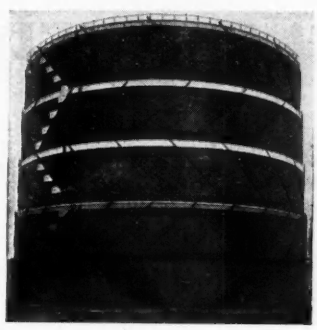
Modern Gas Fitting—Bound.

The reprints in ten separate sixpenny parts of R. N. Le Fevre's Modern Gas Fitting articles from the "Gas Salesman" are known to thousands of fitters, and, though they are now largely superseded by the same author's *Manual of Practical Gas Fitting*, there is still a demand for the booklets, many of which we can supply from stock.

We have a limited remainder of Parts I–VIII inclusive which were bound up together in a stiff board cover for a special purpose, and these we can offer, while stocks last, at half the published price—viz., at 2s. 9d. a copy post free. This is an offer which may appeal to some of those who know so well just where to turn up certain information in the individual booklets, but would like to have it in rather more permanent form, and yet in handy size for the pocket.

Please send orders marked "*Modern Gas Fitting*—bound" to 51, High Street, Esher, Surrey.

As a Precaution against a possible emergency, a link-up between the distribution systems of the Vale of Leven Gas Company and the Dumbarton Gas Company has been effected, in conformity with the National Defence Scheme. An opportunity recently arose to put the scheme into practical operation, and gas was supplied to Dumbarton with results highly satisfactory to both undertakings.



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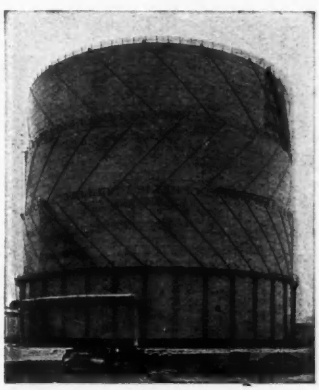

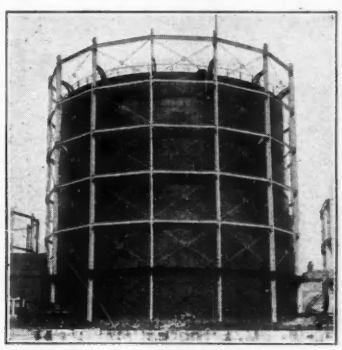

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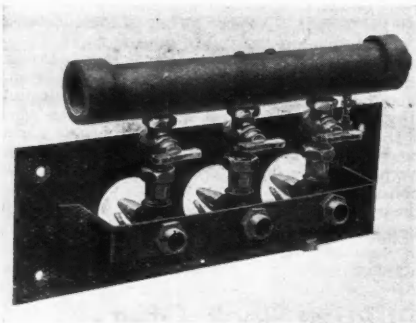

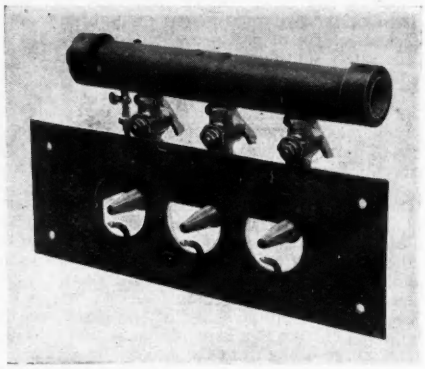

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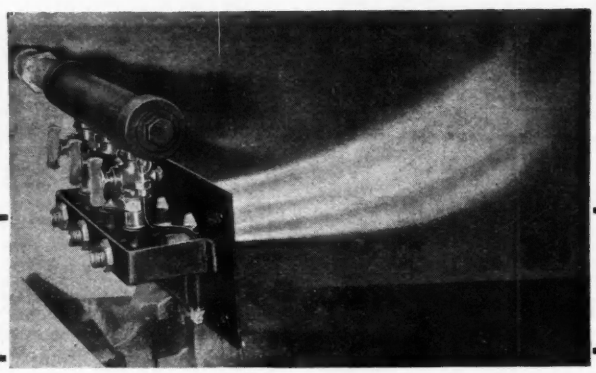

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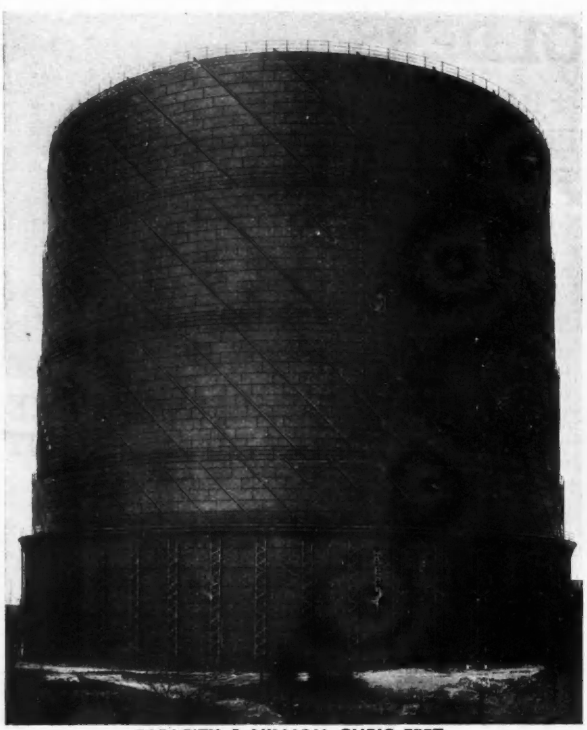

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Gas Products Prices

The London Market

Jan. 27.

Present values of Tar Products in London remain as under: Pitch is nominal; creosote 4¾d. to 5d. per gallon; refined tar 3¾d. to 4d.; pure toluene under the Ministry of Supply Toluene No. 2 Order 2s. 5d.; pure benzole 1s. 10d.; 95/160 solvent naphtha 2s. 3d., and 90/160 pyridine 15s., all per gallon naked; refined crystal naphthalene £23 per ton in bags; all *ex* Makers' Works.

The Provinces

Jan. 27.

The average prices of gas-works products during the week were: Pitch and Crude Tar,* Toluole, naked, North, 1s. 10d. (controlled by the Control of Toluene No. 2 Order, July 5, which fixes the maximum price at which this material may be sold). Coal tar, crude naphtha, in bulk, North 9¼d. to 10d. Solvent naphtha, naked, North, 1s. 9d. to 1s. 10d. Heavy naphtha, North, 1s. 5d. to 1s. 6d. Creosote, *ex* works, in bulk, North liquid and salty, 4¼d. to 4¾d.; Scotland, 4¼d. to 4¾d.; low gravity, 4¼d. to 4¾d. Fuel Grade 4d. to 4¼d. Carbolic acid, 60's, 3s. 9d. to 3s. 10¼d. Naphthalene, £15 to £20. Salts, 75s. to 85s., bags included. Anthracene, "A" quality, 4¼d. to 4¾d. per minimum 40% purely nominal. Heavy oil: Unfiltered anthracene oil (min. gr. 1,080), 5¼d. to 5¾d.; filtered heavy oil (min. gr. 1,080), 5¾d. to 6d.; heavy anthracene oil gr. less than 1,080, 6d. to 6¼d.

* In regard to pitch and crude tar prices we would ask readers to refer to the editorial note in our issue of Sept. 4, 1940, p. 404.

Tar Products in Scotland

Glasgow, Jan. 25.

More activity is noticeable in this market although prices show no material alteration.

Refined tar is not particularly active, with home market value unchanged at 4¼d. to 4¾d. per gallon, and export value at 3¼d. to 3½d. per gallon, both f.o.r. naked.

Creosote oil is in better call with prices steady as follows: Specification oil, 5d. to 5¼d. per gallon; low gravity, 6d. to 6¼d. per gallon; neutral oil, 5¾d. to 6d. per gallon; all *ex* Works in bulk.

Cresylic acid remains quiet with supplies available as follows: Pale, 99/100%, 2s. to 2s. 2d. per gallon; Pale, 97/99%, 1s. 9d. to 1s. 10d. per gallon; Dark, 97/99%, 1s. 6d. to 1s. 7d. per gallon; all *ex* Works in buyers' packages.

Crude naphtha commands, as available, 6¼d. to 7¼d. per gallon *ex* Works in bulk, according to quality.

Solvent naphtha is steady at 1s. 8¼d. to 1s. 9d. per gallon for 90/160 grade and 1s. 4¼d. to 1s. 5¼d. per gallon for 90/190 heavy naphtha.

Pyridine is dull with values nominal at about 17s. to 18s. per gallon for 90/160 grade, and 19s. to 20s. per gallon for 90/140 grade.

Results at Spalding

A net profit of £145 on the working of the past financial year is shown by the accounts of the Spalding Urban District Council. This compares with a deficit of £916 for the preceding twelve months. The gross profit on the present occasion is £6,745, while loan charges, income-tax, &c., amount to £6,600. A satisfactory increase in the consumption of gas for business and domestic purposes has been more than counterbalanced by the enforced reduction in the use of gas for public lighting.

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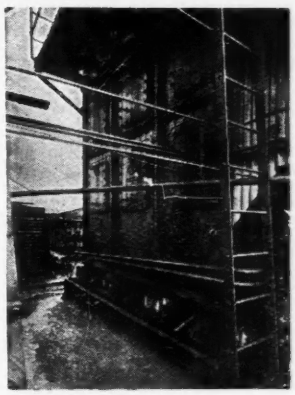
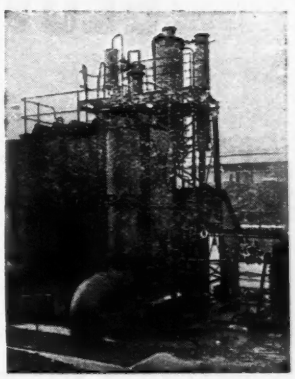
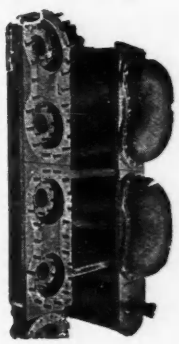
PERMAC JOINTS



"Permac" Joints in a Gas Works



"Permac" Joints in a Gas Works



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GAS STOCKS AND SHARES

Despite a continuance of good news from the East, business on the Stock Exchange was less active than during the previous week, and the general tone was dull. British Funds showed some fractional falls, but subsequently recovered, and a few finally closed with slight gains—2½% Consols remaining steady at 77½. In the home rail market senior prior changes again improved, but the junior stocks gave way in the absence of support. Industrials had a mixed appearance and, apart from a few exceptions, prices were mostly downwards. Rubbers were neglected, but a little business was done among tea shares.

Business was also on the light side in the Gas Market, and the recorded transactions were practically confined to the stocks and shares of the leading undertakings. Although few actual price movements occurred the general undertone of the Market was weak. Gas Light units passed through the week unscathed, but the other two Metropolitan Companies came under a cloud—South Metropolitan closed a further 5½ points down at 45, and Commercial lost 2 to 37½. Croydon maximum dividend stock reacted 4 points to 77½. The only improvement in the Official List was that of Bournemouth 7% maximum with a rise of 5 to 110. On the Provincial Exchanges Newcastle units hardened 3d. to 17s., but Sheffield Consolidated dropped 4 points to 115, business being recorded at this price. The only movement in the Supplementary List occurred in Reading 4% debenture, which fell 4 to 72½.

Quotations on the London and Provincial Stock Exchanges

OFFICIAL LIST

Issue. £	When ex-Dividend.	Dividends. Prev. Hf. Yr. % p.a.	Dividends. Last Hf. Yr. % p.a.	NAME.	Quotations Jan. 23.	Rise or Fall on week.
1,767,439	Sept. 16	7	7	Alliance & Dublin Ord. ...	103—108	...
374,000	Dec. 30	4	4	Do. 4 p.c. Deb. ...	90—95	...
957,608	Nov. 4	5	5	Asscd. Gas & Water U'd'cs Ord.	11/6—13/6	...
500,000	,,	4½	4½	Do. 4½ p.c. Red. Cum. Pref.	14/6—16/6	...
535,545	,,	4	4	Do. 4 p.c. Red. Cum. Pref.	14/6—16/6	...
336,646	,,	4	4	Do. 4 p.c. Irred. Cum. Pref.	12/—14/-	...
561,370	Aug. 12	7	7	Barnet Ord. 7 p.c.	98—103	...
300,000	Oct. 14	1/9⅜	1/4½	Bombay, Ltd.	19/6—21/6	...
690,407	Aug. 19	7	7	Bournemou th 7 p.c. max ...	105—115	+5
362,025	Dec. 16	4	4	Do. 4 p.c. Deb. ...	79—84	...
659,955	Aug. 19	6¾	4⅝	Brighton, &c., 5 p.c. Con. ...	65—75	...
855,000	Sept 30	8	6	Brit. Gas Light Ord.	75—85	...
545,000	Dec. 16	5½	5½	Do. 5½ p.c. 'B' Cum. Pref	105—115	...
120,000	,,	4	4	Do. 4 p.c. Red. Deb.	73—78	...
10,000	Nov. 6, '33	6	4	Cape Town, Ltd., 4½ p.c. Cu. Pf.	¼—¾	...
626,860	July 15	5⅞	6	Cardiff Con. Ord.	89—94	...
24,500	Sept. 23	7	7	Colombo 7 p.c. Pref	19/—21/-	...
764,169	Oct. 7	/11.48	-/11.48	Colonial Gas Assn. Ltd. Ord. ...	14/—16/-	...
400,000	,,	1/3.30	1/3.30	Do. 8 p.c. Pref. ...	19/—21/-	...
1,748,935	July 22	2	3	Commercial Ord.	35—40	—2
620,000	Dec. 9	3	3	Do. 3 p.c. Deb.	57—62	...
286,344	Aug. 19	5	5	Do. 5 p.c. Deb.	87—92	...
807,560	Aug. 12	7	6	Croydon sliding scale	83—88	...
644,590	,,	5	5	Do. max. div.	75—80	—4
620,385	Dec. 30	5	5	Do. 5 p.c. Perp. Deb. ...	90—95	...
179,500	Aug. 19	5⅜	5	East Surrey 'B,' 5 p.c.	60—70	...
176,461	Dec. 16	5	5	Do. 5 p.c. Deb. (Irred.)...	87—92	...
250,000	Nov. 11	4	6	Gas Consolidation Ord. 'B' ...	13/6—14/6	...
250,000	Nov. 11	4	4	Do. 4 p.c. Red. Cum. Pref.	15/—17/-	...
19,123,018	July 29	3⅜	4½	Gas Light & Coke Ord. ...	12/—14/-a	...
2,600,000	,,	3½	3½	Do. 3½ p.c. max.	47—52	—3
4,477,106	,,	4	4	Do. 4 p.c. Con. Pref. ...	67—72	...
2,993,000	July 8	3¾	3¾	Do. 3¾ p.c. Red. Pref. ...	82—87	...
8,602,497	Dec. 2	3	3	Do. 3 p.c. Con. Deb. ...	69—74	...
3,642,770	,,	5	5	Do. 5 p.c. Red. Deb. ...	100—105	...
3,500,000	,,	4½	4½	Do. 4½ p.c. Red. Deb. ...	99—104	...
700,000	Sept. 9	3½	3½	Do. 3½ Red. Deb.	80—85	...
5,600,000	May 13	4	8	Imperial Continental Cap. ...	44—49	...
43,820	July 29	3½	3½	Do. 3½ p.c. Red. Deb. ...	61—66	...
231,978	Aug. 19	5	5	M.S. Utility 'C' Cons.	68—73	...
918,657	,,	4	4	4 p.c. Cons. Pref.	72—77	...
675,000	Nov. 11	†4	†4	Montevideo, Ltd.	52—57	...
300,000	Nov. 18	7	9	Oriental, Ltd.	105—115	...
368,537	Dec. 9	8	6½	Plymouth & Stonehouse 5 p.c.	88—98	...
621,667	Aug. 19	8½	7½	Portsmouth & Gosport Cons.	90—95	...
648,999	Sept. 16	1/1	1/1½	Severn Val. Gas Cor. Ld. Ord.	13/—15/-	...
597,972	,,	-/10⅝	-/10⅝	Do. 4½ p.c. Cum. Pref. ...	15/6—17/6	...
2,528,714	Sept. 2	1/-	-/7½	South East'n Gas Cn. Ld. Ord.	8/—10/-	...
1,000,000	,,	-/10⅜	-/10⅜	Do. 4½ p.c. Red. Cum. Pref.	14/—16/-	...
1,068,869	,,	4	4	Do. 4 p.c. Irred. Cum. Pref.	12/6—14/6	...
6,709,895	Aug. 5	4	4	South Met. Ord.	40—50	—5½
1,135,812	,,	6	6	Do. 6 p.c. Irred. Pref. ...	102—107	...
850,000	,,	4	4	Do. 4 p.c. Irred. Pref. ...	69—74	...
1,895,445	Dec. 30	3	3	Do. 3 p.c. Perp. Deb. ...	58—63	...
1,000,000	Jan. 15	5	5	Do. 5 p.c. Red. Deb. ...	97—102	...
1,543,795	July 22	3	4	South Suburban Ord. 5 p.c. ...	62—67	...
512,825	July 8	5	5	Do. 5 p.c. Perp. Pref. ...	85—90	...
500,000	,,	4	4	Do. 4 p.c. Perp. Pref. ...	63—68	...
250,000	,,	3¾	3¾	Do. 3¾ p.c. Red. Pref. ...	80—85	...
888,587	Dec. 16	5	5	Do. 5 p.c. Perp. Deb. ...	93—98	...
750,541	Aug. 9	5½	5	Scu.hampton Ord.	57—62	...
350,000	Feb. 12	5½	5½	Swansea 5½ p.c. Red. Pref. ...	91—96	...
1,076,495	Aug. 5	5	5	Tottenham & District Ord. ...	62—67	...
338,555	,,	5	5	Do. 5 p.c. Pref.	78—83	...
453,380	Dec. 9	4	4	Do. 4 p.c. Perp. Deb. ...	76—81	...
1,247,505	May 20	4	6	U. Kingdom Gas Cor. Ord. ...	13/—15/-	...
1,085,952	Nov. 25	4½	4½	Do. 4½ p.c. 1st Cum. Pref. ...	13/6—15/6	...
772,709	,,	4	4	Do. 4 p.c. 1st Red. Cum.Pref.	13/—15/-	...
745,263	Dec. 16	4½	4½	Do. 4½ p.c. 2nd Non.Cum. Pf.	12/—14/-	...
1,200,000	Sept. 9	3½	3½	Do. 3½ p.c. Red. Deb. ...	82—87	...
380,606	Aug. 5	7	6½	Uxbridge, &c., 5 p.c.	80—90	...
1,371,138	July 8	3½	4	Wandsworth Consolidated ...	66—71	...
2,525,768	,,	4	4	Do. 4 p.c. Pref.	63—68	...
1,343,964	Dec. 16	5	5	Do. 5 p.c. Deb.	90—95	...
383,745	,,	4	4	Do. 4 p.c. Deb.	75—80	...
558,342	July 15	6	5	Watford & St. Albans Ord. ...	85—90	...
300,000	Dec. 9	3½	3½	Do. 3½ p.c. Red. Deb. ...	84—89	...

SUPPLEMENTARY LIST

Issue. £	When ex-Dividend.	Dividends. Prev. Hf. Yr. % p.a.	Dividends. Last Hf. Yr. % p.a.	NAME.	Quotations Jan. 23.	Rise or Fall on week
351,685	Dec. 16	5	5	Brighton, &c., 5 p.c. Perp. Deb.	88—93	...
28,700	,, 17	5½	5½	Do. 5½ p.c. Red. Deb. 1942 ...	95—100	...
415,250	,, 23	4	4	Bristol Gas Co., 4 p.c. New Deb.	83—88	...
140,205	July 29	7	7	Cambridge, &c., 7 p.c. Cons. 'B'	100—110	...
295,932	Aug. 19	5	5	Cheltenham, 5 p.c. Cons. Ord....	88—93	...
42,500	Dec. 16	4	4	Do. 4 p.c. Perp. Deb....	75—80	...*
150,000	Aug. 12	4	4	Croydon Gas, 4 p.c. Pref. (Irr.)	65—75	...
130,000	Dec. 30	4	4	Do. 4 p.c. Deb. ...	75—80	...
146,700	Aug. 19	5½	5½	East Surrey, 5½ p.c. Pref. 'A' ...	80—90	...
53,220	,, 19	6	6	Do. 6 p.c. Cum. Pref. ...	90—100	...
117,425	Feb. 5	8	8	East Wight, 5 p.c. Cons. Ord. ...	100—110	...
...	Aug. 19	6	4	Eastbourne, 'B' 3½ p.c.... ..	65—75	...
239,135	Nov. 11	5	5	Gas Consolidation 'A' Ord. (£1)	13/—15/-	...
156,600	Aug. 19	5	5	Hampton C't, 5 p.c. Cons. Ord.	68—73	...
18,000	Dec. 2	7	7	Malta & Med'n., 7 p.c. 1st Pref.	55—65	...
10,845	,, 2	7½	7½	Do. 7½ p.c. 2nd Pref.	55—65	...
50,000	Aug. 19	£5 19 6	£5 4 6	Mid. South. Util., 'A' Cons. 5 p.c.	60—70	...
65,000	Aug. 12	5	5	North Middlesex, 5 p.c. Pref. ...	87—92	...
70,000	Sept. 9	5	5	Plymouth & Stone., 5 p.c. Deb.	87—92	...
76,501	Dec. 30	4	4	Reading, 4 p.c. Perp. Deb. ...	70—75	—5
74,777	Sept. 30	4	4	Romford, 4 p.c. Debs. (Reg.) ...	77—82	...
21,000	Dec. 16	5	5	Slough, 5 p.c. Perp. Deb. ...	87—92	...
211,740	,, 30	5	5	Southampton, 5 p.c. Red. Deb.	90—95	...
363,575	Dec. 30	5	5	Tottenham, 5 p.c. Reg. Red. Mt.	94—99	...
202,019	Oct. 14	6½	6½	Tunbridge Wells, 4 p.c. Scale ...	70—80	...
135,257	June 10	5	5	Uxbridge &c., 5 p.c. Perp. Deb.	88—93	...

PROVINCIAL EXCHANGES

					Quotations Jan. 17.	
47,756	July 26	6	5	Bath Cons.	94—98	...
122,577	July 22	7	6	Blyth 5 p.c. Ord.	100—105	...
1,667,250	July 15	5	5	Bristol, 5 p.c. max.	90—93	...
120,420	Dec. 16	4	4	Do. 1st 4 p.c. Deb.	92½—94½	...
415,250	,,	4	4	Do. 2nd 4 p.c. Deb.	91—94	...
328,790	,,	5	5	Do. 5 p.c. Deb.	107—110	...
157,150	Aug. 5	6½	8	Chester 5 p.c. Ord.	98—101	...
92,500	Dec. 16	4	4	Do. 4 p.c. Pref.	79—84	...
36,430	,,	3½	3½	Do. 3½ p.c. Deb.	79—84	...
41,890	,,	4	4	Do. 4 p.c. Red. Deb. ...	93—97	...
542,270	Aug. 12	9	6	Derby Cons.	100—105	...
55,000	Dec. 16	4	4	Do. 4 p.c. Deb.	77—82	...
10,000	Aug. 19	10	10	Great Grimsby 'A' Ord. ...	165—175	...
6,500	,,	10	10	Do. 'B' Ord. ...	165—175	...
79,000	,,	10	10	Do. 'C' Ord. ...	155—165	...
732,000	Aug. 26	4	4	Hartlepool G. & W. Cn. & New	61—63	...
2,167,410	Aug. 19	6	6	Liverpool 5 p.c. Ord.	97—100	...
245,500	Dec. 16	5	5	Do. 5 p.c. Red. Pref. ...	97½—100½	...
306,083	July 15	4	4	Do. 4 p.c. Deb.	99—101	...
20,000	Dec. 23	5	5	Long Eaton 5 p.c. Pref.	9—11	...
80,000	,,	5	5	Do. 5 p.c. Deb.	92—97	...
2,430,267	July 29	5 7/10	5	Newcastle and Gateshead Con.	16/6—17/6a	+/-3
682,856	,,	4	4	Do. 4 p.c. Pref.	75—77	...
776,706	Dec. 23	3½	3½	Do. 3½ p.c. Deb.	80—85	...
277,285	Oct. 21	5	5	Do. 5 p.c. Deb. '43	97—102	...
274,000	July 26	5	5	Newport (Mon.) Ord.	89—93	...
13,200	Sept. 16	8½	7	Pontyp'l Gas & W. 10 p.c. 'A'	11½—12½	...
13,600	,,	6	5	Do. 7 p.c. 'B'	9½—10½	...
40,000	,,	5	6	Do. 7 p.c. 'C'	9½—10½	...
106,280	Aug. 5	8	10	Preston 'A' 10 p.c.	157—167	...
188,219	,,	7	7	Do. 'B' 7 p.c.	113—123	...
1,806,339	Aug. 26	6½	6½	Sheffield Cons.	114—116	—4
95,000	Jan. 6	4	4	Do. 4 p.c. Deb.	96—98	...
332,351	Feb. 5	6	6	Sunderland 6 p.c. max. ...	107—112	...
140,778	Aug. 12	5	5	Weston-super-Mare Cons.	80—85	...
64,338	Dec. 30	4	4	Do. 4 p.c. Deb.	75—85	...
33,340	,,	7½	7½	Do. 7½ p.c. Deb.	135—143	...

a.—The quotation is per £1 of Stock. * Ex div † Price free of income-tax.

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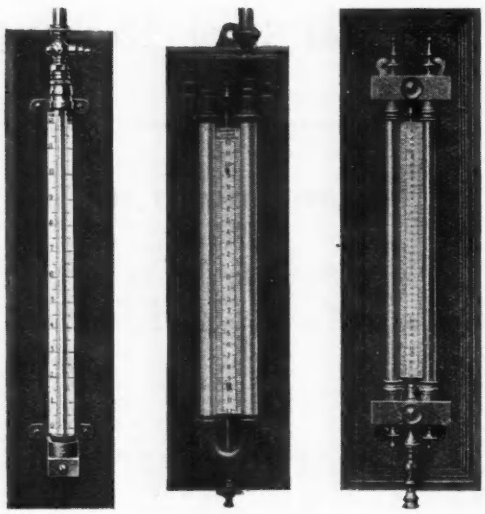

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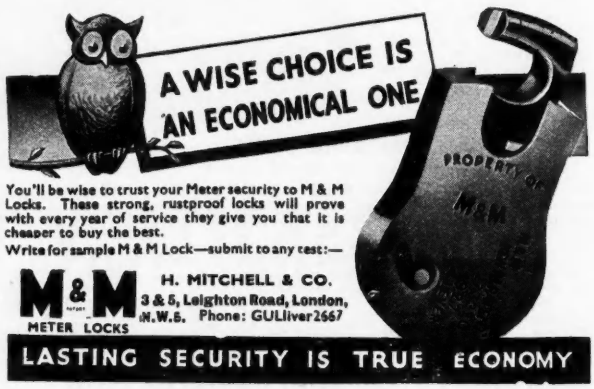

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